Popular Astronomy

Vol. LIV, No. 2 **FEBRUARY, 1946** **Whole No. 532**

Astronomy and Ornithology

By **WILLIAM A. RENSE**

There would not appear to be much connection between the study of birds and the study of astronomy. However, there is one field of investigation wherein the ornithologist and the astronomer have found it to be of mutual advantage to collaborate, and as a consequence of this cooperation some interesting facts and possibilities have revealed themselves. Unfortunately, the happy conjunction of the astronomer and ornithologist has not been fully exploited, and the benefits which would accrue to both have not been reaped.

Probably it all started when some unknown amateur astronomer, while looking at the moon one night, saw birds passing over the disc. It was during the migratory season, and his interest was aroused. The observation was mentioned to some ornithologist who immediately saw the possibility of studying the nocturnal flight of birds in this manner, but who did not push the idea very far. In 1902 H. A. Winkenwerder[1] published a paper entitled "The Migration of Birds with Special References to Nocturnal Flight" in which he analyzed bird counts taken by observers viewing the moon from different locations during the course of a night. He showed how estimates of the direction of the birds may be made, and drew conclusions concerning the extent and times of migration. A few years later the astronomer, Joel Stebbins,[2] showed how the method of parallax may be used to calculate the height of birds passing in front of the moon. F. W. Carpenter[3] then published a paper giving the results of the application of Stebbin's work to a particular migration.

Since that time very few organized attempts to study bird flight by this astronomical method have been made. Yet the method is of special importance because it is the only direct way available for observing the birds in their migratory flights at night. In fact, even in the daytime the passing of migratory birds proceeds almost entirely unobserved because the birds are lost against the bright background of the sky (although their calls may sometimes be heard). Day-time flights, however, also have been detected with the telescope, this time by the observation of the birds against the sun's disc (a suitable eyepiece being used). Most

[1] *Bulletin of Wisconsin Natural History Society*, Vol. 2, No. 4, p. 117-263, 1902.

[2] "A Method of Determining the Heights of Migrating Birds," POPULAR ASTRONOMY, Vol. XIV, No. 2, p. 65-70, 1906.

[3] "An Astronomical Determination of the Heights of Birds During Nocturnal Migration," *The Auk*, Vol. 23, p. 210-217, 1906.

data about bird migrations have been acquired by more or less indirect methods such as bird concentration studies on the ground in particular regions at given times, banding of birds, twilight observation of flights, and the study of accidents to birds in flight such as at lighthouses. It does not appear offhand that merely watching a few birds pass over the sun or moon is going to lead to nearly as much knowledge about the flight of birds as do the methods just mentioned. But the fact is that a great deal of important information can be garnered. The main purpose of this paper is to point out what this information is and to suggest to amateur astronomers an organized plan for the observations of the flight of birds against the sun or moon. It is hoped that this plan will appeal to them to the extent that they might be willing to give some of their time to this topic and thus help the ornithologists learn more about the details of bird migration.

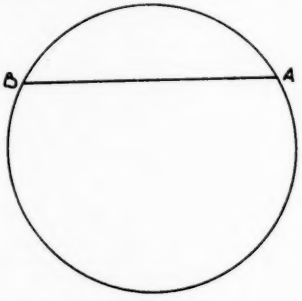


FIGURE 1

Suppose the path of a bird across the disc of the full moon has been accurately marked from observations through a telescope. Let AB in Figure 1 be this path. What information can be obtained from this? The answer is, the exact direction in which the bird was flying, assuming that it was flying essentially horizontally the fraction of a second it took to cross the moon (a safe assumption). To see this, refer to Figure 2. The observer is at O. OY is the North-South line, and OX, the

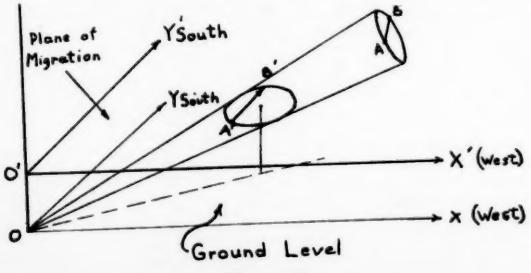


FIGURE 2

East-West line. Y′ O′ X′ is a plane parallel to the horizon and through the path of the bird. The cone-shaped surface included by the moon's circular edge and the observer's eye cuts this plane in an ellipse. A′ B′ is the path of the bird along the ellipse, and AB is this same path as projected and seen against the moon. Obviously, for any A′ B′ there is a unique AB, and *vice-versa*, so that if AB is given one should be able to calculate the direction in which the bird is flying. The calculation is made by means of the following equation:

$$\tan \eta = \frac{2 \cos \theta \sin \psi_o + \sin 2 Z_o \cos \varphi_o \sin \theta}{2 \cos \theta \cos \psi_o - \sin 2 Z_o \sin \varphi_o \sin \theta} \qquad (1)$$

Here the symbols have these meanings:

η = the azimuth (reckoned West from the South point) of the direction of flight of the bird.
ψ_o = azimuth of moon's center at time of observation.
Z_o = zenith distance of moon's center at time of observation.
θ = position angle of direction of path on moon's disc.

This last angle, θ, is found by drawing a line parallel to AB through the moon's center (Figure 3) and measuring the angle from the axes

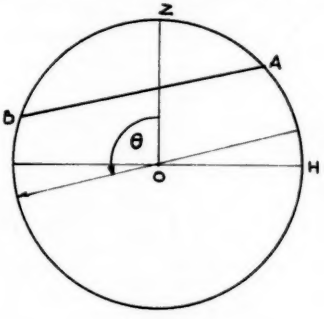


FIGURE 3

as shown. The OZ axis is the intersection with the moon's disc of the great circle passing through the zenith and the moon's center. The direction OZ on the disc must be known for the time of observation. OH is an axis perpendicular to OZ and will be referred to as the horizontal axis.

What else can be learned from a plot of the path as in Figure 1? Not much, unless the distance of the bird is known. But the distance of the bird can be found if two observers, not far apart, have made observations of the same bird. Suppose A″ B″ (Figure 4) is the path obtained by the second observer, who is situated at the same height several feet from the first observer along a line perpendicular to the line to the moon. Then for the bird at any point C on AB there is a corresponding point C″ on A″ B″ (found by drawing the horizontal line as shown in Figure

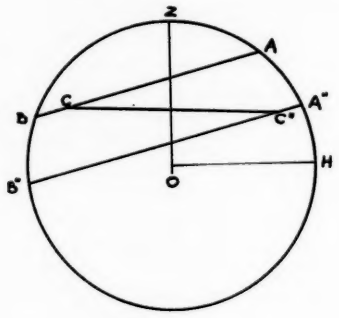


FIGURE 4

4) which represents the position of the bird as seen by the second observer at the same instant. The distance CC″ changed to angular measure (radians) is the "parallax" of the bird. Figure 5 helps make

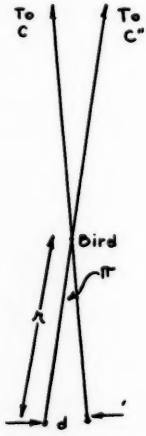


FIGURE 5

this clearer. The distance CC″ may be changed to radians by multiplying the ratio of CC″ to the length of the moon's diameter in the figure by the angular diameter of the moon in radians (about 9×10^{-3}). The distance of the bird is calculated from the formula:

$$r = d/\pi, \tag{2}$$

where:

r = the distance of bird,
d = distance apart of observers (Figure 5 or Figure 8),
π = the shift in path of bird in radians (CC″, Figure 4 or Figure 7).

Usually, however, it is the height of the bird above the ground that is desired. From Figure 6 and from (2) we see that with sufficient

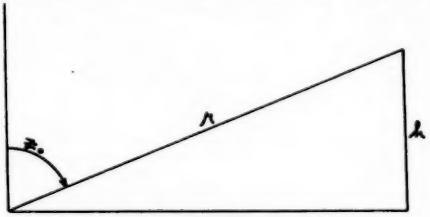


FIGURE 6

accuracy:

$$h = r \cos Z_o = d \cos Z_o/\pi, \tag{3}$$

where h is the height above the ground and Z_o is the zenith distance of the moon's center. Sometimes it is better for the two observers to be situated one above the other. For example, this would be desirable when the birds are flying due north and the moon is due west or due east. Then standing to the left or right would cause the paths to shift along themselves and no displacement would be observed. But by the observers being located one above the other, a maximum effect is produced. The shift would be from C to C″ as in Figure 7, and the calculations

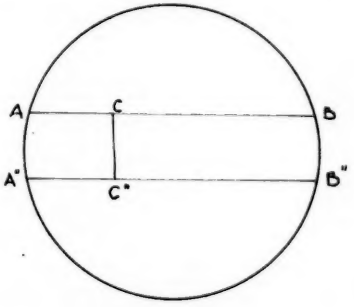


FIGURE 7

would be carried out as before except that the distance, d, would be measured as in Figure 8.

So much for the two important results, direction and distance, which come out of the study of the path of a single bird. We next consider the tracing down of facts which come out of a study of the paths of many birds in the course of a night. Many of our conclusions will be of a statistical nature and are to be interpreted as such. This is not a consequence of difficulties inherent in the theory; exact mathematical solutions can be made. It is rather a result of the fact that birds which are

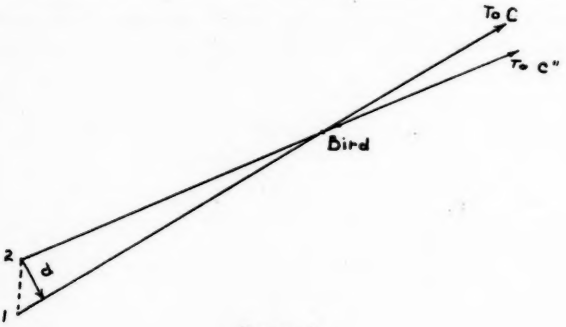


FIGURE 8

seen against the moon or sun in this manner represent only a very small fraction of the birds that are actually engaged in the migration over the whole sky.

One factor very helpful in describing a migration of birds is to be able to state how many birds participate in the migration. There are several ways of indicating the bird density, so to speak, in a migration. The definition which will be used in this article is the following: bird density for a given migration is the number of birds per hour which pass a mile of the earth's surface perpendicular to the direction of flight. It is this quantity, ρ, which we now show can be found from observations of birds passing across the moon.

Suppose that in the course of a short time interval (about 15 minutes to an hour) the paths of several birds have been observed and recorded, as in Figure 9. All of the paths are nearly parallel, as would be ex-

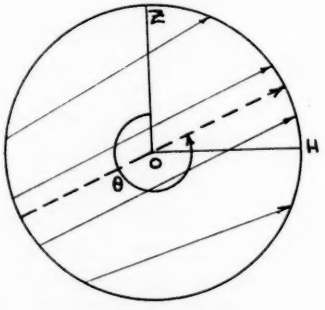


FIGURE 9

pected if the birds are flying in the same direction. The dotted line through the center is drawn to represent the average direction of flight. The vertical and horizontal axes, OZ and OH, must be known, and then θ, the position angle of the dotted line, is measured. From equation

(1) the average direction of flight, $\overline{\eta}$, is then determined. Next, consider the ellipse (Figure 2) which represents the intersection of the cone of observation with the plane of migration. It is assumed that all the birds are flying in this plane. In Figure 10 this ellipse is reproduced.

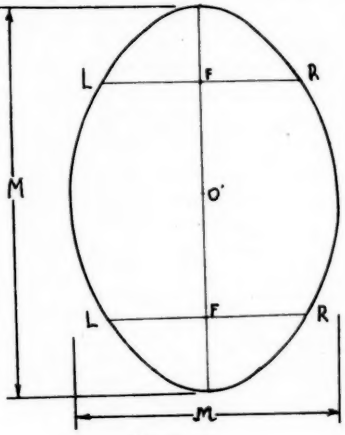


FIGURE 10

M is the longest diameter and m is the shortest. The F's are the focal points and O' is the center. LR is the latus rectum. From the properties of an ellipse, and from the geometry of Figure 2, we can write:

$$M = \overline{h}\,\mu/\cos^2 Z_m,\quad m = \overline{h}\,\mu/\cos Z_m, \tag{4}$$

$$LR = \overline{h}\,\mu, \tag{5}$$

$$O'F = \tfrac{1}{2} M \sin Z_m. \tag{6}$$

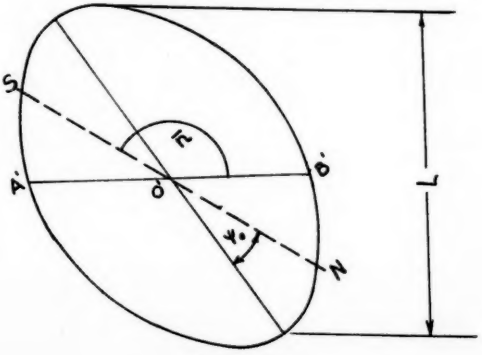


FIGURE 11

Here $\overline{h}$ is the average height of the birds, Z_o the average zenith distance of the moon's center, and μ the angular diameter of the moon in radians (about 9×10^{-3}). From these equations it is easy to determine M, m, LR, and O'F, and to sketch the ellipse to scale. The North-South direction on the ellipse can then be drawn in by measuring off the angle equal to the moon's average azimuth, ψ_o, from the longest diameter, as in Figure 11. Then by measuring off $\overline{\eta}$ from the S-N line, the direction of flight, A' B', across the ellipse can be found. By drawing lines parallel to A' B' at the extremities of the ellipse as shown in Figure 11, and by referring to the scale of the diagram one can arrive at the value of the distance, L, which represents the length along the earth's surface perpendicular to the flight such that any bird which passes this length would have been seen somewhere on the moon's disc. It follows that:

$$\rho = 5280 \cdot n/\tau L, \tag{7}$$

where ρ is the bird density, n is the number of birds flying in the same direction observed in the interval τ hours, and L is the length in feet obtained as described above.

The above result gives only a very rough value of bird density in the region of the ellipse unless parallax measurements have been taken and yield a good average value for h. Of course, if the parallax measurements show that some birds fly high, some low, values for each group of birds can be found. If parallax measurements are not taken, $\overline{h}$ must be estimated and the value of ρ then gives only the correct order of magnitude of bird density.

If the moon is not full the above method still can be used to find ρ. The solid angle to the moon under these circumstances does not form an ellipse in cutting the plane of migration but rather a more complicated curve made up of the projections of the terminator and the outer rim of

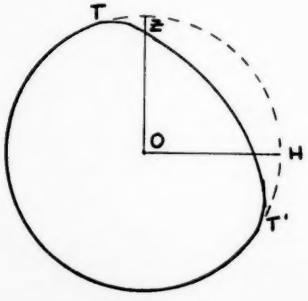


FIGURE 12 (a)

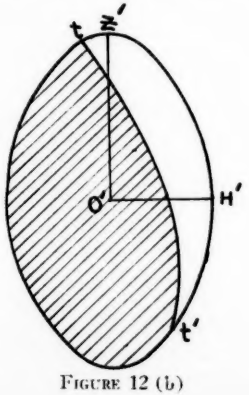


FIGURE 12 (b)

the moon. Figure 12 (a) represents the gibbous moon and Figure 12 (b), its projection on the plane of migration. By measuring the angles θ, say for OT and OT', treating these lines separately, their directions on the ellipse may be found from equation (1) and t and t' located by the method used to locate A' and B' in Figure 11. The terminator projection may then be roughly sketched in, as in Figure 12 (b). Another way of doing this is to choose three or four points along the terminator and find their ΔZ's and $\Delta\psi$'s in radians, Figure 13. Multiply the ΔZ's

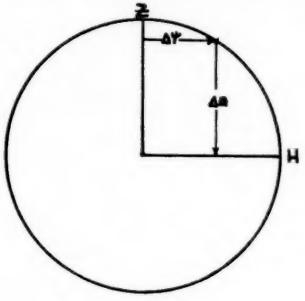


FIGURE 13

by the ratio of M to m and use these last numbers as the O' Z' coordinates in Figure 12 (b), while $\Delta\psi$'s remain unmodified as the O' H' coordinates. The scale must be such that O' H' represents $\mu/2$, or about 4.5×10^{-3} radians. The three or four points thus located in the ellipse make it easy to sketch the terminator.

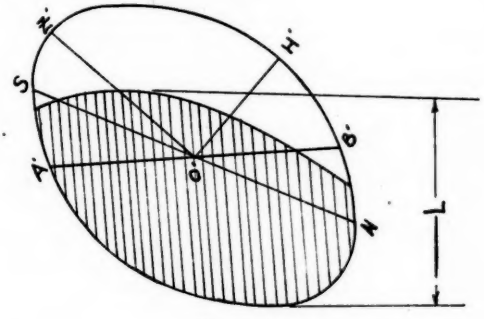


FIGURE 14

The procedure for finding L is similar to that mentioned before for the full moon, except that not the entire ellipse, but only the portion corresponding to the moon's projection is treated. An example is shown in Figure 14.

A bird migration is a great and very interesting natural occurrence.

Millions of birds participate. The spring and fall are the seasons which find most of the birds on the move. In Figure 15 are shown the more

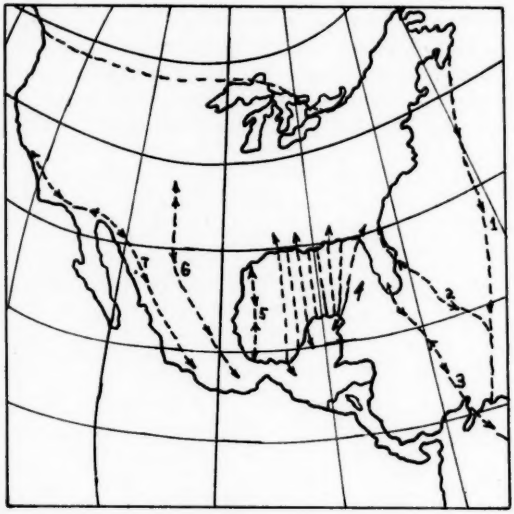


FIGURE 15

PRINCIPAL MIGRATION ROUTES OF NORTH AMERICA (AFTER W. W. COOKE).

well-known belts of bird migration in the United States. The exact boundaries of most of these are not known. It can not be emphasized enough that if thousands of systematic observations such as those outlined in this paper are made throughout the country every spring and autumn, or even during all the year, the problem of learning the details about bird migration will largely be solved. Those observations could be carried out by amateur astronomers or others interested in the topic. Only a small telescope and the moon or sun are needed. Thus we see here another example of the advantages arising from cooperation among scientists and workers in different fields. The astronomer helps the ornithologist to successfully attack bothersome aspects of an important problem in bird study, and the ornithologist in turn gives the astronomer another excuse for looking through a telescope.

It is not an easy job to make organized observations of bird flights across the moon's disc. The birds usually cross in a fraction of a second and would be missed if attention is relaxed only for an instant. Experience shows that it is nearly always difficult to make out details of the bird's structure that might lead to identification. A scarcely detectable flapping of the wings might be the only indication that the object which passed the moon was a bird. Occasionally the bird is large enough or

close enough to reveal its features through its silhouette, but to depend upon the telescope for direct identification is a precarious procedure. In migration studies the birds will likely be between 1000 feet and a mile away, so that good focus for birds is expected through a small telescope magnifying about 30 times and focused for the moon. Sometimes insects pass the field of view and may be mistaken for birds except for the fact that they are decidedly out of focus. Binoculars reveal some birds, but not as effectually as a telescope of the size just referred to. On the other hand, telescopes magnifying too much (over 50 times) begin to introduce focus troubles and make it necessary to watch the enlarged image of the moon piecemeal, thus permitting some birds to escape notice. Large telescopes, unless driven by a clockwork mechanism, have the added disadvantage of requiring almost continuous adjustment of centering of the moon's image because of the earth's diurnal motion. A small telescope magnifying between 15 and 30 diameters evidently is the best for bird study of this kind.

As to the number of birds that might be seen against the moon on any given night for any given time interval, say one half-hour, it might be mentioned that anything from no birds up to hundreds may be seen, depending upon the season of the year and the presence or absence of migratory birds in the vicinity. At the Louisiana State University Observatory on April 22, 1945, 59 birds flying north were observed in fifteen minutes. This corresponded to a flight density of about 51,000 birds per mile each hour. The birds were without doubt migratory birds, many of which possibly had come over the gulf from Central America. One month later, May 23, at the same station, no birds were observed for hours on end, as would be expected since the migration season was virtually over. To show the variation from hour to hour at a given station during a typical night in the migration season, the following data taken at the same station are presented. On the night of April 26-27, 23 birds were observed between about 8:00 and 9:00 o'clock, 32 birds between 10:30 and 1:00 o'clock, and only one bird between 1:00 and 4:30 o'clock. This is not to be taken to mean that birds tend always to fly early in the night. Nocturnal migrations on different nights are variable as a result of many factors of which weather is a highly important one.

The details for making the observations leading up to values of ρ for given time intervals depend to some extent upon the experience of the observer and the equipment available. The following procedure is suggested for those having the necessary facilities and also the requisite background in astronomical theory. A simplified program of observation for less experienced persons will be presented later.

OBSERVERS: Two.

RECORDER: One.

APPARATUS, *etc.*: (1) Two telescopes, powers between 15 and 30,

preferably both of same power. Eyepieces giving erect images and containing cross-hairs are best.

(2) Sidereal clock or Standard Time clock.

(3) Tape measure or rule.

(4) Diagrams or photographs of moon showing details of surface.

(5) Ephemeris or Nautical Almanac.

DATA: (1) General weather conditions (surface winds, direction of clouds, etc.).

(2) Latitude and longitude of observers.

(3) The N-S line on the moon's surface (path of hour circle through moon's center) is to be sketched on the diagram of the moon. By letting the moon drift in the telescope the E-W line can easily be found. The N-S line is perpendicular to this. The moon's terminator (if moon is not full) is also to be sketched in. These lines will change slightly in the course of the night, but not enough to materially affect the results. From these data the OZ and OH axes may be found, as will be shown later under "Calculations."

(4) The two observers might be about 5 to 8 feet apart, seated either left and right of the line to the moon, or else one above the other. The distance, d, as shown in Figure 5 or Figure 8, whichever is appropriate, will be measured. As time goes on the observers will find it necessary to shift. The new d's and the times should be recorded.

(5) When a bird is observed each observer will call out the 'coordinates' of the first and last points of the path on the moon. One scheme for doing this is to imagine the moon to be a clock face and to read the 'times' of entrance and exit. Cross-hairs will help. Thus, in Figure 16,

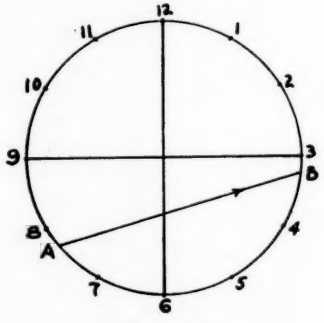


FIGURE 16

if AB is the bird path, the 'coordinates' would be about 7:40-3:15. The 12-6 line should be fixed with respect to the features on the moon, the two observers and the recorder using the same reference marks. The recorder will jot down the standard or sidereal time (or both) of each observation. Birds observed simultaneously should be so marked to aid

later in parallax determination. Comments on the appearance of the bird, speed of flight, etc., might also be recorded. Observations should begin as early in the evening as possible and should continue as late into the night as convenient. Continuous all night observations are especially helpful, though not necessary, to the study of bird migrations. Whatever scheme is used in assigning coordinates, it is essential that from them the bird's path can be later reproduced with accuracy on the diagram of the moon.

CLCULATIONS: (1) *Zenith distance,* Z_o, *and aximuth,* ψ_o, *of moon at any time.*

Choose three times, well distributed throughout the whole night's observation period. Calculate Z_o and ψ_o for each of these times using the following equation (accuracy to within 0.5 degree is sufficient):

$$\cos Z_o = \sin \delta \sin \phi + \cos \delta \cos \phi \cos t, \quad (8)$$

$$\sin \psi_o = \sin t \cos \delta / \sin Z_o, \quad (9)$$

where

δ = declination of moon,
ϕ = latitude of observer,
t = hour angle of moon at the time.

This last quantity, t, may be found from the relationship:

$$t = \theta - a, \quad (10)$$

where θ is the local sidereal time and a the right ascension of the moon. Corrections for the moon's parallax may be neglected in obtaining a and δ from the almanac.

When Z_o and ψ_o have been found for the three different times, curves can be plotted from which the value of each for any time during the night can be read off. If necessary four points or more may be plotted to obtain the curves.

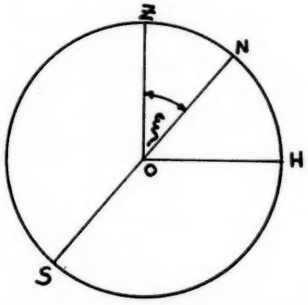


FIGURE 17

(2) *Location of vertical and horizontal axes on moon at any time.* Your observational data have given you the location of the N-S line on the moon's surface. Let this line be represented by N-S in Figure 17.

Then the axis OZ makes an angle ξ with this line that can be computed at any time by the equation:

$$\sin \xi = \sin \psi_o \cos \phi / \cos \delta. \qquad (11)$$

By using the appropriate ψ_o's, this angle can be found for several different times and a curve plotted from which ξ at any time may be read off. From values of ξ thus obtained, OZ and OH axes can be drawn for any time on the diagram of the moon.

(3) *Heights of birds.* For each bird which was observed simultaneously by both observers, a plot of the paths on the moon is made. The OZ and OH axes are located and the quantities r and h computed using equations (2) and (3) and following the procedure associated with them. Before a calculation is begun, a common sense check might be made to determine whether the bird really represents the same bird and not two different birds crossing at the same time. If the paths are not shifted in the proper sense ('left' observer sees it to right on moon, or 'above' observer sees it below on moon) the paths are not for the same bird and the calculations for the height should not be made.

(4) *Determination of average direction of migration,* $\overline{\eta}$. Divide the entire period of observations into half-hour periods (a shorter or greater time interval may be used depending upon the accuracy required and the number of birds seen). What follows applies to each interval. Plot all the observed bird-paths and draw a line as in Figure 9 representing the average direction. Locate the OZ and OH axes for the middle of the time interval and measure θ. Compute η using equation (1) and record as $\overline{\eta}$. If your plots show the existence of two or more general directions, find $\overline{\eta}$ for each.

(5) *Determination of bird density,* ρ. For each of your time intervals proceed as follows: Consider all the birds having a given $\overline{\eta}$. Refer to your parallax calculations to see whether the parallax birds in this group all have about the same height. If so, average these heights and use as $\overline{h}$. Birds having this $\overline{\eta}$ but whose heights have not been measured are assumed to have this average height also. Substituting in equations (4), (5), and (6), obtain information about the size of the ellipse for the middle of the time interval. Sketch the ellipse to scale. Allow, if necessary, for the moon's phase as illustrated in Figure 12. Find the value of L as shown in connection with Figure 11 (or Figure 14 if the moon is not full). From (7), ρ, is then found. If the birds having a given $\overline{\eta}$ show a tendency to be flying at two or more different heights, ρ for each height may be found. In this case, non-parallax birds may be divided proportionally in counting n for each group.

With the finding of the ρ's for the successive time intervals the most tedious part of the work is done. It must, however, be clear to anyone who is statistically minded, that only by combining results of many observers located in different regions for all times of the year can a clear picture of bird migration as a whole be drawn. One observer in one locality can do no more than contribute one stroke of the brush in the painting of the whole picture. It will take the integrated efforts of many assiduous observers all over the country, even all over the world, to complete the task. But the job can be done. The amateur astronomers might be the ones to insure its success.

Optional method of finding Z_o and ψ_o. If an alt-azimuth mounting with circles is available, zenith distances and azimuths of the moon may be directly measured at different times and a curve plotted as outlined in (1) of "Calculations," above. The north star could be used for finding the North point.

Optional method for finding the OZ and OH axes on the moon. If the eyepiece of a telescope has two cross-hairs set at right angles it is not hard to line these up so one appears vertical (and the other horizontal). With the intersection near the center of the moon the directions of the OZ and the OH axes may easily be traced and these axes then marked on the diagram of the moon.

Procedure when only one observer is working. Virtually all of the data that can be obtained with two observers and a recorder are within the reach of one observer who is also his own recorder. Only the parallax measurements must be omitted. In calculating bird densities, an average height, $\overline{h}$, must be guessed at on the basis of previous experience with bird migrations, or else simply arbitrarily assumed. If a single observer is limited in equipment or does not possess the astronomical information needed to carry through the above procedures, he can still contribute to the study of bird migrations by obtaining the minimum data consisting of bird counts between given times, and a statement giving the approximate direction in which the birds are flying.

Sample Data and Calculation. The following set of data is hypothetical and serves only to illustrate the astronomical method for studying bird migrations.

OBSERVERS: John A. Fields, Robert R. Gunther.

RECORDER: Charles B. Dobson.

APPARATUS: (1) Two 2-inch terrestrial telescopes mounted on tripods and provided with eyepieces magnifying 20 times. Each eyepiece has six intersecting cross-hairs making angles of 30°.

(2) Pocket watch giving Central Standard Time accurate to one-half minute.

(3) Tape measure.

(4) Several diagrams of full moon showing seas and prominent craters, etc., all to scale.

(5) *The American Nautical Almanac.*

DATA: (1) Sky clear. Wind about 5 miles/hour from northwest. May 20, 1945.

(2) Latitude $= \phi = 38° 30'$ N, Longitude $= 95° 00'$ W.

(3) The N-S line on the moon was located and sketched in on one of the diagrams. The terminator was also sketched in (Figure 18).

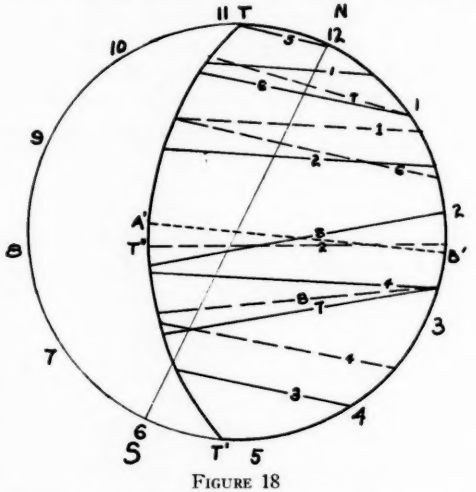


FIGURE 18

(4) The distance, d, with observer Gunther right, and observer Fields left of line to moon, was measured as 4 feet 7 inches for the first bird, 5 feet 6 inches for all other birds.

(5) The following bird observations (the first set for the night) were taken between 6:30 and 7:00 P.M. The N-S line was used as the 12-6 line (Figure 16). Starting time 6:30 P.M. C.S.T.

Bird	Observer Fields	Time	Observer Gunther
1	10:00 - 12:30	6:31	9:15 - 1:15
2	9:00 - 1:30	6:34	8:00 - 2:15
3	7:00 - 4:00	6:36	.....
4	8:00 - 2:45	6:41	7:30 - 3:30
5	.....	6:43	11:00 - 12:00
6	10:00 - 1:00	6:45	9:30 - 1:40
7	7:00 - 2:40	6:52	10:15 - 1:00
8	7:45 - 2:00	7:00	7:15 - 2:45

CALCULATIONS. (1) *Zenith distance,* Z_o, *and azimuth,* ψ_o, *for any time.* (a) Times used for plotting the curve are 6:00 P.M., 7:00 P.M., and 8:00 P.M. C.S.T. From the *Almanac,* sidereal time, midnight, Greenwich, May 21 = 15 hr. 53 min.

6 P.M. C.S.T. May 20 = 0 A.M., May 21, Greenwich civil time
7 P.M. C.S.T. May 20 = 1 A.M., May 21, Greenwich civil time
8 P.M. C.S.T. May 20 = 2 A.M., May 21, Greenwich civil time

6 P.M. = 15 h. 53 m. Greenwich Sidereal time
6 P.M. = 9 h. 33 m. local sidereal time = θ_1

7 P.M. = 16 h. 53 m. Greenwich Sidereal time
7 P.M. = 10 h. 33 m. local sidereal time = θ_2

8 P.M. = 17 h. 54 m. Greenwich Sidereal time
8 P.M. = 11 h. 34 m. local sidereal time = θ_3

(b) Hour angles. From *Almanac* $a_1 = 11$ h. 41 m., $a_2 = 11$ h. 43 m., $a_3 = 11$ h. 45 m., $\delta_1 = +7°.5$, $\delta_2 = +7°.0$, $\delta_3 = +7°.0$.

t_1 = hour angle at 6 P.M. = $\theta_1 - a_1 = -2$ h. 08 m. = 2 h. 08 m., E = —32°.0.
t_2 = hour angle at 7 P.M. = $\theta_2 - a_2 = -1$ h. 10 m. = 1 h. 10 m., E = —17°.5.
t_3 = hour angle at 8 P.M. = $\theta_3 - a_3 = -0$ h. 11 m. = 0 h. 11 m., E = —3°.0.

(c) *Points for curves* Z_o vs. *time and* ψ_o vs. *time*. From equations (8) and (9), using t_1:

$\cos Z_o = \sin 7°.5 \sin 38°.5 + \cos 7°.5 \cos 38°.5 \cos (-32°.0)$.
or $Z_o = 43°.0$.
$\sin \psi_o = [\sin (-32°.0) \cos 7°.5]/\sin 43°.0$,
or $\psi_o = -51°.5$ (East).

In a similar manner the other points are found for the two curves, and the curves plotted using C.S.T. as abscissa.

(2) Finding of OZ and OH axes. At 6 P.M., from (11):

$\sin \xi = [\sin (-51°.5) \cos 38°.5]/\cos 7°.5$, or $\xi = -38°.0$.

The ξ's are found for the other points and a curve plotted using C.S.T. as abscissa.

(3) *Heights of birds.* The paths of all birds for both observers were plotted (Figure 18). Field's are shown dotted. For each of the pairs of paths corresponding to simultaneous observations, the OZ and the OH axes were drawn in (with the help of the ξ *vs.* time curve) and the shift along OH measured and changed to radians, using 9×10^{-3} radians as angular diameter of the moon. Observations of the bird numbered 7 were not used, since the shift is in the wrong direction (there were probably two different birds then). For the first bird, from (2) and (3):

$$r = 4.6/1.55 \times 10^{-3} = 2970 \text{ ft.}$$
$$h = r \cos Z_o = (2970)\ (\cos 38°.0) = 2340 \text{ ft.}$$

The other birds gave values close to these, and the average for all was

$\overline{h} = 2200$ ft.

(4) *Value of* $\overline{\eta}$. From the lines in Figure 18, the "average" line A'B' was drawn in, and its θ found to be —42°. Substituting in (1) we get:

$$\tan \overline{\eta} = \frac{2 \cos (-42°) \sin (-38°) + \sin 73° \cos (-38°) \sin (-42°)}{2 \cos (-42°) \cos (-38°) - \sin 73° \sin (-38°) \sin (-42°)},$$

whence

$$\overline{\eta} = 119°.$$

This means that the general direction of flight of the observed birds is 29 degrees N of W. (The quadrant of the angle is best determined by recalling the approximate direction of the birds as seen through the telescopes.)

(5) *Calculation of* ρ. (a) From equations (4), (5), and (6) we have:

$$LR = 2200 \times 9 \times 10^{-3} = 19.8; \quad M = 2200 \times 9 \times 10^{-3}/\cos^2 36.5 = 30.7,$$
$$m = 2200 \times 9 \times 10^{-3}/\cos 36.5 = 24.7; \quad O'F = \tfrac{1}{2}(30.7)(\sin 36.5) = 9.14.$$

Drawing these to scale, we get the ellipse of Figure 19. Consider the

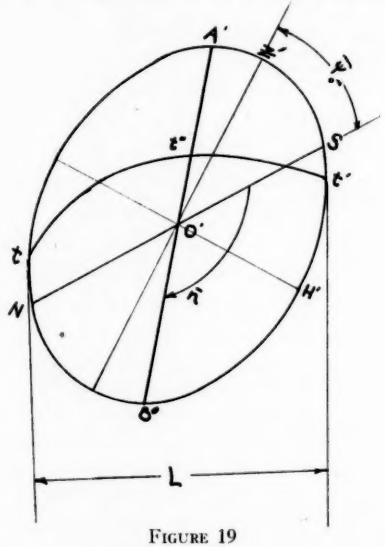


FIGURE 19

points T, T′, and T″ along the terminator in Figure 18. For point T, $\Delta\psi = 3.8 \times 10^{-3}$ radians and $\Delta Z = 2.5 \times 10^{-3}$ radians. Axes OZ and OH for time 6:45 P.M. are used. ΔZ multiplied by M/m is 3.11×10^{-3} radians. Since O′H′ in Figure 19 represents 4.5×10^{-3} radians, the modified ΔZ and the unchanged $\Delta\psi$ give a point, t, in the Figure as shown. Similarly, t′ and t″ are found and the moon in phase is sketched in. L is found as indicated in the Figure, and is 25.0 feet. Letting n be 7 (average number of birds seen by one observer) and substituting in (7), we get, finally:

$$\rho = (7)\ (5280)/(0.5)\ (25) = 2960 \text{ birds/mile/hour.}$$

ACKNOWLEDGMENT. The writer is greatly indebted to Professor

George H. Lowery, Curator of the Museum of Zoology, Louisiana State University, for pointing out the importance of the astronomical methods of observing bird flights and for providing the inspiration necessary to extend these methods. Professor Lowery has applied them in a study of trans-Gulf migration, the results of which will appear in a paper entitled "New Evidence of Trans-Gulf Migration" to be published in *The Auk*.

Louisana State University, Baton Rouge, La.

Some Deductions Made from a Correlation of Lake Michigan Water Levels with the Sun-Spot Cycles

By BEN HUR WILSON

The association of "Solar Phenomena" with the current of human affairs dates back at least as far as the beginning of astrology. It has been, however, for only little more than a century that records of various types of solar disturbances have been kept with sufficient accuracy to permit their correlation with terrestrial-human relationships susceptible of rational analysis.

To date, considerable has already been learned from this source, and yet many other things suspected, although not entirely accepted, concerning the direct influence which cyclic variations in the quantity and quality of solar radiation have upon the earth's weather and climate, and indirectly upon all living things which are definitely affected by their own terrestrial environment. Even human beings as well, it appears, cannot wholly escape the influence of these emissions, and likewise respond in many ways to the mysterious rhythms now commonly conceded to be of solar origin.

There remains, however, one important, highly controversial matter, which has not yet been definitely proven to the entire satisfaction of everyone—nor has it been disproven. That is, are these solar disturbances the primary or direct cause, or are they themselves the result of outside influences at work, concerning which we are not yet fully informed, which may, perhaps, be partially responsible for both. Some have intimated, and made serious attempts to show, that there may be measurable interplanetary forces operating which basically might account for all such phenomena.

The type and variation of these responses are too numerous to mention. They range from the sublime to the ridiculous. While it is true that scientists were once skeptical as to their actual reality, there are indeed few who will now deny that there is at least some valid correlation between solar phenomena, as indexed by the "Sun-spot Numbers," and

many important terrestrial affairs. Information which may be added to the growing accumulation of evidence seems always to be well received.

From the standpoint of commerce and industrial development, the water level of all the Great Lakes, and Lake Michigan in particular, is of great interest and importance. This is due, not only to the unusually large volume of water-borne traffic carried on its surface, but also to the necessity of determining in advance as accurately as possible the amount of water which may safely be diverted from the lower end of this Lake for sanitary, domestic, and industrial purposes; and, for the maintenance of satisfactory conditions for the navigation of the "Lakes-to-Gulf Waterway," via the "Chicago Drainage Canal" and the "Illinois Valley Outlet."

This is a matter which has long been a "bone of contention" between the various states and the many other interests involved, including such major ones as the Eastern Power Corporations operating at Niagara Falls; the Dominion of Canada and the St. Lawrence Valley System; and all of the numerous Navigation and Docking Companies now functioning upon the several Great Lakes, together with their related industries. So important has this problem become that it has been made the subject of considerable litigation, some phases of which having been already "aired" all the way up through the lower Courts, to the Supreme Court of the United States.

The beginning of this process of water diversion from the lower end of Lake Michigan, giving rise to all the corresponding problems involved, dates back nearly a century, to the building of the old original Illinois and Michigan (I & M) Canal, begun in 1836 and completed in 1848, between Lake Michigan at Chicago and the city of La Salle, at which place it merged with and into the Illinois River. This pioneer canal being of small calibre, obtained most, if not all, of the water required for navigation and the operation of its locks from the local tributary streams entering the valley of the Des Plaines River, whose basin lies wholly to the west or the "Gulf" side of the mid-continental divide. Therefore, except as a matter of historical precedent, it has no immediate bearing upon the problem now being considered.

The next invasion into the "sacred" waters of Lake Michigan took place upon the completion of the "Chicago Sanitary" canal in 1900, the construction of which was begun almost a decade previously in 1892. A much smaller lateral canal known as the Sag Canal, serving the Calumet basin, to the south, was later added to the system, being built between the years 1911 and 1922. The building of these canals, a Herculean task, was made necessary on account of the fact that it early became imperative that the great metropolis draw on the Lake for its entire water supply to be used for domestic, sanitary, and industrial purposes. That the sewage of the city should be permitted to drain into the Lake

was unthinkable, and there being no other practical solution of the problem at hand, the so-called "Drainage Canal," was dug through the divide, thus artificially diverting water from Lake Michigan into the Gulf of Mexico, which normally would have flowed out into the Atlantic via Niagara Falls and the St. Lawrence River.

Technically, it was possible to perform this engineering feat, owing to unique physiographic features prevailing at the site of the diversional channels, which are too well known to require full discussion here. Opposite Chicago, that is, to the west, the elevation of the mid-continental divide at its lowest point was only about eight feet above the mean elevation of Lake Michigan. It is said, that in early days, during rainy seasons, it was possible for Indians and traders to take their canoes from the Lake through and across this divide into the valley of the Des Plaines river without portage.

This situation was taken advantage of in the planning and construction of the "Drainage Canal," which was accomplished by deepening or channelling out the bed of the Chicago River, via its South Branch, to a point near its head waters, and thence trenching a new channel through solid bedrock, running in a southwesterly direction, of a sufficient fall and depth to bring about an inversion of the flow of its waters, causing it to come in through its mouth at Lake Michigan, and to pass out through the valley of the Des Plaines, at its confluence with the "Drainage Canal" near the village of Lemont. At the time of construction, the matter of causing a river to flow "up hill" through what was formerly its normal valley, (which of course as everybody knows is an erroneous statement), was heralded all over the world as a remarkable feat of engineering.

The natural level of Lake Michigan, based upon its elevation above mean tide sea level, (New York Harbor Datum Plane), was evidently first made a matter of record in the year 1860. The maximum or highest level for the year is the one usually published by the United States Lake Survey. Within each year, however, there is a considerable variation in elevation, ranging from a low, which usually occurs in January, though occasionally as early as December, and sometimes as late as March, to a high which occurs in mid-summer, usually in July or August. This variation from high to low during the year, while not always consistent, is generally of the magnitude of about one foot.

For the reader's convenience, we have taken the "Annual Sun-spot Numbers," as revised by Wolf and Wolfer, and arranged them in parallel columns (See Table I) so that they may be readily compared with the annual maximum elevation of Lake Michigan above sea level. It is this set of data that we propose to here analyze for the purpose of making some of the more obvious and logical deductions, from the correlation of the fluctuating lake levels with the "Sun-spot Cycle Numbers."

TABLE I

LAKE MICHIGAN WATER LEVELS

The Highest Point Above Mean Sea Level*
For Each of Indicated Years 1860-1944
Together With the Annual Sun-spot Number**

Yr.	Elev.	SSp.	Yr.	Elev.	SSp.	Yr.	Elev.	SSp.
1860	583.1	95.7	1888	582.1	6.8	1916	581.2	57.1
1861	583.3	77.2	1889	581.6	6.3	1917	581.8	103.9
1862	582.9	59.1	1890	581.4	7.1	1918	581.9	80.6
1863	582.4	44.0	1891	580.9	35.6	1919	581.6	63.6
1864	581.9	47.0	1892	580.9	73.0	1920	581.0	38.7
1865	581.8	30.5	1893	581.2	84.9	1921	580.5	24.7
1866	581.4	16.3	1894	581.3	78.0	1922	580.6	14.7
1867	582.0	7.3	1895	580.1	64.0	1923	579.8	5.8
1868	581.4	37.3	1896	579.8	41.8	1924	579.5	16.7
1869	581.8	73.9	1897	580.8	26.2	1925	578.5	44.3
1870	582.4	139.1	1898	580.8	26.7	1926	578.6	63.9
1871	582.6	111.2	1899	580.9	12.1	1927	579.5	69.0
1872	581.2	101.7	1900	580.6	9.5	1928	580.6	77.8
1873	581.9	66.3	1901	581.0	2.7	1929	582.3	65.0
1874	582.1	44.7	1902	580.7	5.0	1930	581.1	35.7
1875	582.0	17.1	1903	580.7	24.4	1931	579.1	21.2
1876	583.4	11.3	1904	581.3	42.0	1932	578.6	11.1
1877	582.5	12.3	1905	581.5	63.5	1933	578.7	5.7
1878	582.4	3.4	1906	581.3	53.8	1934	578.1	8.7
1879	581.4	6.0	1907	581.4	62.0	1935	578.6	36.1
1880	581.9	32.3	1908	581.7	48.5	1936	578.7	77.1
1881	582.0	54.3	1909	580.9	43.9	1937	578.6	114.4
1882	582.6	69.7	1910	580.4	18.6	1938	579.6	109.5
1883	583.1	63.7	1911	579.9	5.7	1939	580.0	88.7
1884	582.8	63.5	1912	580.6	3.6	1940	579.5	67.3
1885	583.1	52.2	1913	581.1	1.4	1941	579.1	47.5
1886	583.4	25.4	1914	580.6	9.6	1942	580.2	30.5
1887	582.7	13.1	1915	580.1	47.4	1943	581.5	16.3
						1944	580.9	

*Source—United States Lake Survey Report.

**Revised numbers by A. Wolfer (Vol. 30 *Monthly Weather Review*).

TABLE II

BREAKDOWN OF THE MAXIMUM TO MAXIMUM (MINUS ONE) SUN-SPOT CYCLE PERIODS FOR YEARS 1860-1944** AND THE ANNUAL MEAN DISCHARGE IN SECOND FEET FLOW* 1900-1944

	MAXIMUM CYCLE 1.			MAXIMUM CYCLE 2.	
Year	El. (ft.)	Sp. No.	Year	El. (ft.)	Sp. No.
1860	583.1	96	1870	582.4	139
1861	583.3	77	1871	582.6	111
1862	582.9	59	1872	581.2	102
1863	582.4	44	1873	581.9	66
1864	581.9	47	1874	582.1	45
1865	581.8	30	1875	582.0	17
1866	581.4	16	1876	583.4	11
1867	582.0	7	1877	582.5	12
1868	581.4	37	1878	582.4	4
1869	581.8	74	1879	581.4	6
			1880	581.9	32
10 yrs.	5822.0	487	1881	582.0	54
Mean	582.2	48.7	1882	582.6	60
			13 yrs.	7568.4	659
			Mean	582.2	50.7

MAXIMUM CYCLE 3.

Year	El. (ft.)	Sp. No.
1883	583.1	64
1884	582.8	64
1885	583.1	52
1886	583.4	25
1887	582.7	13
1888	582.1	7
1889	581.6	6
1890	581.4	7
1891	580.9	36
1892	580.9	73
10 yrs.	5822.0	347
Mean	582.2	34.7

MAXIMUM CYCLE 4.

Year	El. (ft.)	Sp. No.	***Discharge Cu. ft./sec.
1893	581.2	85	
1894	581.3	78	
1895	580.1	64	
1896	579.8	42	
1897	580.8	26	
1898	580.8	27	
1899	580.9	12	
1900	580.6	10	3,110
1901	581.0	3	4,045
1902	580.7	5	4,302
1903	580.7	24	4,971
1904	581.3	42	4,798
12 yrs.	6969.2	418	21,226
Mean	580.8	34.8	4,245

MAXIMUM CYCLE 5.

Year	El. (ft.)	Sp. No.	***Discharge Cu. ft./sec.
1905	581.5	64	4,477
1906	581.3	54	4,473
1907	581.4	62	5,116
1908	581.7	49	6,443
1909	580.9	44	6,495
1910	580.4	19	6,833
1911	579.9	6	6,896
1912	580.6	4	6,937
1913	581.1	1	7,829
1914	580.6	10	7,814
1915	580.1	47	7,739
1916	581.2	57	8,201
12 yrs.	6970.7	417	79,252
Mean	580.9	34.7	6,604

MAXIMUM CYCLE 6.

Year	El. (ft.)	Sp. No.	***Discharge Cu. ft./sec.
1917	581.8	104	8,726
1918	581.9	81	8,827
1919	581.6	64	8,594
1920	581.0	39	8,346
1921	580.5	25	8,352
1922	580.6	15	8,459
1923	579.8	6	8,043
1924	579.5	17	9,115
1925	578.5	44	7,982
1926	578.6	64	8,284
1927	579.5	69	8,451
11 yrs.	6383.3	528	93,179
Mean	580.3	48.0	8,471

MAXIMUM CYCLE 7.

Year	El. (ft.)	Sp. No.	***Discharge Cu. ft./sec.
1928	580.6	78	10,012
1929	582.3	65	9,450
1930	581.1	36	8,357
1931	579.1	21	8,180
1932	578.6	11	8,100
1933	578.7	6	8,004
1934	578.1	9	8,125
1935	578.6	36	8,095
1936	578.7	77	6,607
9 yrs.	5215.8	339	74,930
Mean	579.4	37.7	8,326

MAXIMUM CYCLE 8.

Year	El. (ft.)	Sp. No.	***Discharge Cu. ft./sec.
1937	578.6	114	6,433
1938	579.6	110	6,484
1939	580.0	89	4,862
1940	579.5	68	?
1941	579.1	48	?
1942	580.2	31	?
1943	581.5	16	3,472
1944	580.9	?	3,412
8 yrs.	4639.4	?	?
Mean	579.9	?	?

*Cubic feet per second discharge as measured at Lockport Control Works.

**Sun-spot Number reduced to nearest whole number.

***Discharge represents total amount of direct diversion, plus domestic and industrial pumpage, etc., of the Chicago Sanitary District.

To discuss thoroughly every phase of the matter involving the varying levels of the Great Lakes and the related solar and climatic phenomena, it may readily be seen, would immediately open up a major

research problem of greater complexity than should here be undertaken. However, there are several more evident phases of the subject which will be quite apparent to all, each one having considerable interest, that may here be considered to good advantage. First, before going further allow the writer to state, that he does not wish for a moment to imply that the idea of correlation of lake levels with sun-spot cycle numbers is original with him. It has, I am sure, been previously suggested by others on several occasions.

By an examination of Table II, it will be seen that we have followed a rather unorthodox method in breaking down the data, arranging the Sun-spot Cycles from years of Maximum activity to Maximum (minus one), rather than the usual arrangement of Minimum to Minimum. This was done for two sufficiently good reasons. (1) It so happens that the year 1860, when the maximum level for Lake Michigan was first accurately determined and made a matter of record, fell on a year of maximum sun-spot activity. This gives us the opportunity of studying seven complete cycles, and one more (No. 8) which is almost complete. And (2), in the consideration of the matter of fluctuating lake levels, it is usual to think of periods in terms of from "high to high," rather than from "low to low." It will be noted that the disturbance of the natural balance (status quo) by man, did not occur until about the middle of Cycle 4, when water was for the first time diverted from Lake Michigan, upon any effective scale, near the completion of the "Sanitary Canal" project, in 1900.

A recapitulating summary involving the totals shown in the above Table II, for each of the eight cycle periods, will doubtless help to clarify such analysis of the data as may be undertaken. Inasmuch as Cycle 8 is incomplete, full data are in this case not yet at hand.

Cycle No.	Years	Mean El.	Mean Sp. No.	Mean Diversion
1	10	582.2	48.7	None
2	13	582.2	50.7	None
3	10	582.2	34.7	None
4	12	580.8	34.8	4,245 (5 Yrs.)
5	12	580.9	34.9	6,604
6	11	580.3	48.0	8,471
7	9	579.4	37.7	8,326
8	8	579.9	Data not at hand.	

It is a remarkable fact that for the first three cycles (before the intervention of man), the mean elevation for each complete cycle remained exactly the same. This was true in spite of the fact that the cycle periods were of different lengths, and the cyclic elevation range varied from 1.9 to 2.5 feet. The mean cyclic Sun-spot Number variation for the three periods, however, ranged from 34.7 to 50.7, which is a matter that is difficult to explain. We would suggest, that the following given reasons might well be considered, and we shall state them in the order of their probability as we now see them.

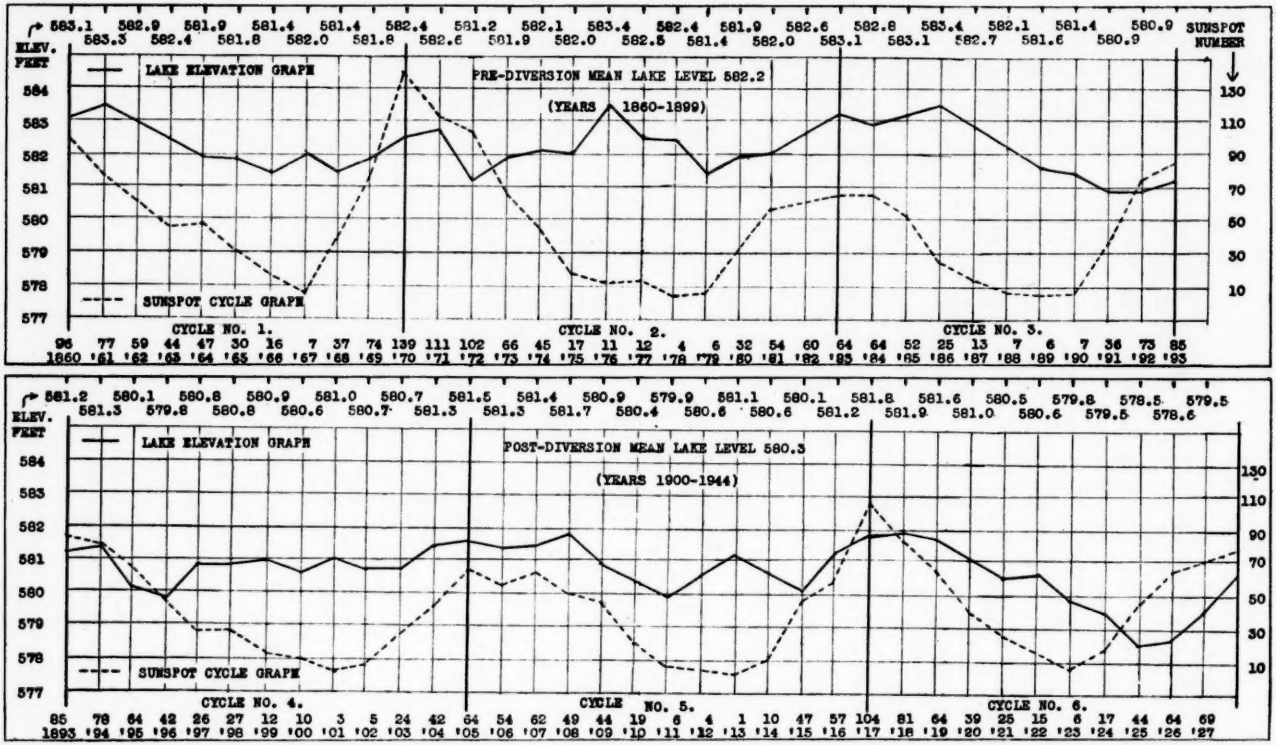
It may be, (1) that sun-spots are not the cause, or at least not the en-

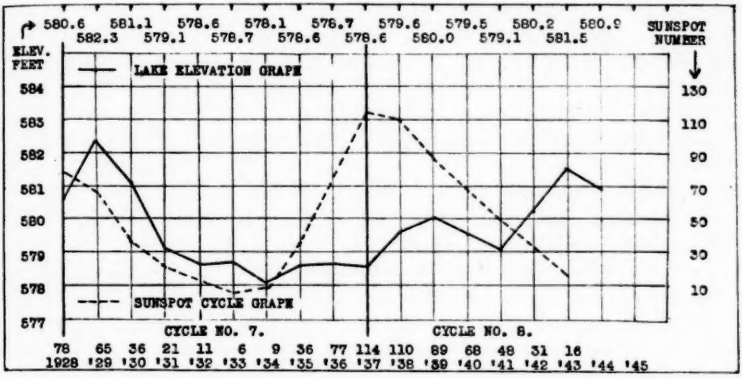
tire or sole cause, of terrestrial climatic cycles, but that both are the result of outside influences working either independently of, or in conjunction with solar disturbances to produce these irregularities. (2) That the sun-spot influence, however it may operate, may not always be in direct proportion to the visible number of spots. That is, the matter of size or visibility of the disturbed solar areas may be subordinate to strength of the forces which may emanate therefrom to produce the results. And (3), that the sun-spot numbers as produced by the Wolf and Wolfer formula are not always wholly accurate, but are only an approximation of the true value, as indicated by the best available data. There are yet other factors which doubtless enter into the problem of which space forbids discussion at this time.

We come now to the matter of the determination of the degree of correlation between the sun-spot cycle numbers and the mean annual elevation of Lake Michigan. First, let us show that such correlation actually does exist by a comparison of the closely coincident dates of the maximum and the minimum periods. It will be noted that for every complete cycle, each sun-spot maximum year coincides or is followed immediately by the periodical year of highest lake elevation; and likewise, each sun-spot minimum year also coincides approximately with the years of minimum elevation,—two even anticipating the event by a period of one year. For analytical purposes let us view facts set forth in the following tabulation.

Cycle No.	Sun-spot Max. Yr.	Elevation High Year	Time Lag.	Sun-spot Min. Yr.	Elevation Low Year	Time Lag.
1	1860	1862	+2 yrs.	1867	1868	+1 yr.
2	1870	1871	+1 yr.	1878	1879	+1 yr.
3	1883-4	1886	+2 yrs.	1889	1891	+2 yrs.
4	1893	1894	+1 yr.	1901	1900	—1 yr.
5	1905	1905	+0 yr.	1913	1915	+2 yrs.
6	1917	1918	+1 yr.	1923	1924	+1 yr.
7	1928	1929	+1 yr.	1933	1935	+2 yrs.
8	1937	1939	+2 yrs.	1943	1942	—1 yr.
			Mean 1.2 yrs.			Mean 0.9 yr.

It is apparent, in each instance, that there is a small but definitely consistent time lag between the tie-in points of the data curves; the mean lag for the maximum period being 1.2 years, while that of the minimum period is 0.9 year. This represents an average lag for both maximum and minimum which is of the order of about one year. This is, we believe, as it should be. It is only natural to assume that variations in weather conditions affecting rainfall would not be immediately reflected in lake levels since all of the precipitation coming within the drainage basin would not at once find its way into the lake, to aid in the maintenance of its elevation. Much of it would occur as snow, during the fall and winter months, and would therefore not be released to flow towards the lake until melting the following spring. It is also well known that as much as from 30% to 60% of all the water which


ELEV. FEET
LAKE ELEVATION GRAPH
SUNSPOT CYCLE GRAPH
PRE-DIVERSION MEAN LAKE LEVEL 582.2
(YEARS 1860-1899)
POST-DIVERSION MEAN LAKE LEVEL 580.3
(YEARS 1900-1944)
SUNSPOT NUMBER
CYCLE NO. 1.
CYCLE NO. 2.
CYCLE NO. 3.
CYCLE NO. 4.
CYCLE NO. 5.
CYCLE NO. 6.



falls (depending upon the season and the texture of the local mantle-rock) settles into the soil thereby becoming a part of that great body of ground-water, which moves even more slowly towards its destination than the snowwaters. The remaining water, which forms the surface run-off, also requires a definite time to complete its journey, and may also be more or less retarded in passing through lakes, ponds, and swampy places, etc. Nothing further need be said concerning the actual precipitation lag (time elapsed between evaporation and precipitation) which varies somewhat in different regions, due to factors which are more or less obvious, but altogether too complicated to receive attention here.

For the purpose of discussing the diversion problem and its effect upon sun-spot-lake-level correlation, the above graphs will prove illuminating. Only a cursory examination of them need be made to observe their manner and interest. Let us first explain what is meant by the terms "discharge" and "diversion." Both are measured in cubic feet per second flow as determined at the Sanitary District Control Works, located near Lockport, Illinois. Formerly this place was the sole control station, the flow being regulated by the manipulation of a series of manually operated gates, above the spillway dam. Recently, however, gates have also been constructed at the mouth of the Chicago River, to prevent its waters from backing out into Lake Michigan during flood periods. These gates now likewise aid in the control of the discharge flow. The "discharge" represents the total amount of diversion now permissible under the present Supreme Court ruling, plus such domestic and industrial pumpage as may be required to operate the homes and industries of the Chicago region, most of which eventually finds its way into the "Sanitary Canal" as water waste and sewage.

This "discharge," which was originally begun upon an appreciable scale in the year 1900, it will be seen, was very moderate at first, amount-

ing on the average for the first five-year period to only 4,245 cubic feet per second. As the city of Chicago grew rapidly throughout the ensuing decades, it not only became desirable but necessary to materially increase this amount to an average of 6,604 cu. ft. per sec. for Cycle Period 5; 8,471 for Cycle Period 6; and 8,326 for Cycle Period 7. Inasmuch as Cycle Period 8 is not as yet completed, its mean diversion cannot now be stated.

So large an amount of diversion as indicated for cycles 5, 6, and 7, it is apparent, could operate in only one way, and that to bring about a gradual lowering of the mean lake level. While the total, stated in cubic feet per second does not seem great, its aggregate in feet even when spread out over so large an area as Lake Michigan, embracing as it does some 22,450 square miles, is considerable and commensurable, amounting, as per formula, to an annual reduction over the entire area of some .05 feet per 1000 cubic feet of discharge per second.

$$(60 \times 60 \times 24 \times 365.25 \times 1000)/(5280 \times 5280 \times 22{,}450) = .0494$$

During the first five years, it would seem as if the diversionary effect became cumulative, for when we multiply the total discharge for the period, *i.e.*, 21,226, by the 1000 cubic feet per second factor, .05, we find $(21.226 \times .05)$ the product to be 1.1 feet for the entire period. This added to the mean lake elevation for Cycle 5, or $580.8 + 1.1$, restores the mean elevation of the lake to 581.9, which is within .3 ft. of the normal mean for the three preceding undisturbed Cycles (1, 2, and 3). Here, indeed, is a tangible example of effects which are produced when man steps in to interfere with balances previously set up by nature.

From here our story becomes more complicated, yet still quite significant. Owing to the large number of more or less intricate factors involved, no very definite deductions may be made. There are one or two matters, however, which we shall discuss in closing, the solution of which may have practical bearing upon some of the problems involved. Let us state, that we do not hold arbitrarily to all the conclusions drawn, as there may be fallacies present in them which are not now apparent.

First, it will be noted, that while the total discharge for the three subsequent Cycles — 5, 6, and 7 — is several times that of Cycle 4, the mean elevation of the lake for those periods was not pulled down anyways nearly proportionately to the amount of the diversion. Without further explanation or statement of facts, this matter might appear quite damaging to any theory which we should attempt to set up. In our own mind this anomaly may be accounted for in the following manner. For Lake Michigan, there exist two separate and distinct outlets, and herein lies the solution to our problem.

The first or natural outlet is at the upper end, through the "Straits of Mackinac," where the waters of Lake Michigan empty into Lake Huron. Since the waters of Lake Michigan stand on the average of only about one foot above those of Lake Huron the normal flow through

the straits is slight, being only that which is required to keep them in balance. There being no artificial barrier between them, this flow may be regulated only by natural causes such as the shifting of the levels in either lake, due to variable regional rainfall, or that of the prevailing winds. At the lower end of Lake Michigan, an entirely different situation prevails. Here is an artificial outlet (The Chicago Drainage Canal) through which the flow is regulated by gates, the amount which may be diverted being limited only by the capacity of the canal, at the lower end of which there is a drop of more than forty feet, through the "Lockport Locks." The total amount which the Lake level might possibly be lowered by the employment of unlimited diversion, however, is in the final analysis determined by the depth of the canal, which in this instance is about twenty feet.

By further study of Table II, it will be noted that the cumulated discharge in terms of cubic feet per second flow for the Cycle periods 5, 6, and 7, shows totals which are as follows:

	Cycle 5	Cycle 6	Cycle 7
Mean Annual Discharge	6,604	8,471	8,326
Total Cycle Discharge	79,(252)	93,(179)	74,(930)
1000 cu. ft. factor	.05	.05	.05
Total effect	3.96 ft.	4.65 ft.	3.75 ft.

By deducting these amounts from what would probably be the stable or normal mean elevation of Lake Michigan without diversion, as determined from the data shown for Cycles 1, 2, 3, and 4, we obtain estimated elevations for each period, which we might have expected to obtain should Lake Michigan have had only a single outlet:

	Cycle 5	Cycle 6	Cycle 7
Probable Mean Elevation	582.2	582.2	582.2
Total Cycle Discharge	3.9	4.7	3.7
Calculated Mean Elevation	578.3	587.5	578.5

However, it will also be observed from Table II that the actual mean elevation for each of the three cycles involved is somewhat above the calculated values, here shown:

	Cycle 5	Cycle 6	Cycle 7
Actual Mean Elevation	580.9	580.3	579.4
Calculated Elevation	578.3	587.5	578.5
Excess Elevation	2.6	2.8	0.9
1000 cu. ft. factor	.05	.05	.05
Excess Diversion	52,000	56,000	18,000
Years of Cycle Period	12	11	9
Mean annual Excess	4,333	5,091	2,000

This discrepancy, or rather anomaly, may be accounted for in only one manner, which is as follows. Without diversion at the lower end of the lake, the entire increment of water into the lake, (rainfall plus

inflows, minus evaporation plus subsurface drainage) would draw off naturally through the Straits of Mackinac. Upon the opening of a new outlet at the lower end of the Lake, moderate diversion would not at first greatly affect the outflow through Lake Huron. As discharge at the lower outlet was increased and became cumulative, the Lake level would gradually be pulled downward, a point eventually being reached where the elevation of both lakes balanced. Any discharge from Lake Michigan beyond that point must be thereafter at the expense of the waters which normally would have flowed out through Lake Huron, and as the level of Lake Michigan gradually declined, outflow through the Straits of Mackinac would soon have ceased altogether were it not for the fact that Lake Michigan and its drainage basin lies almost wholly within the region having an average annual rainfall of from 30 to 40 inches. It is, therefore, safe to estimate the average annual infall plus inflow for the entire lake to be in the neighborhood of about three (3) feet. From this it will be apparent that the total discharge, being approximately but 10% of the total outflow, even when taken upon a cumulative basis is insufficient to affect permanently the mean lake level, inasmuch as the annual inflow is more than ample to restore that which is lost through diversion, by the simple reduction of the outflow via Lake Huron.

Further discussion of the matter of diversion, at this time, especially of its economic influence, would carry us far beyond the realm appropriate to any astronomical consideration, and so we must therefore close with the following brief summary. (1) While the mean annual lake levels vary distinctly within the sun-spot cycles, their cyclic mean remains constant at elevation 582.2, so long as no unnatural diversion takes place. This is a natural balance. (2) While the sun-spot mean does not correlate with the cyclic elevation, this may be accounted for on the basis of certain postulations. (3) The cyclic correlation is marked and the time lag between tie-in points is consistent and natural. (4) Upon the advent of artificial discharge, there was instant response as reflected by a drop in the mean cyclic lake elevation. (5) As discharge was increased, the mean cyclic lowering of the lake level was not proportionate, which may be accounted for by the fact that the excess amount of outflow via Lake Huron is accordingly diminished. (6) That the lowering of the Lake level is not cumulative beyond a certain point, is due to the relatively high rainfall of the region which is ample to overcome the very moderate amount (10%) of discharge which is now permissible.

Doubtless, there are yet other worthwhile deductions which might well be made from more detailed study of the data, together with the facts shown on the graph herein submitted, but for the present we shall allow the matter to rest as stated awaiting further developments.

Joliet Astronomical Society, Joliet, Illinois.

Development of Photographic Photometry without Objectives

By G. A. TIKHOV*

In 1942 I published an article on photographic photometry without objectives.† The principle of this method is that a bright star or a planet gives in a lensless camera a certain illumination on the photographic plate, which results in a blackening on the negative. In the case of a parallel beam the illumination on the photographic plate is naturally independent of the distance between the plate and the diaphragm placed instead of the objective which is removed; the diameter of the circle exposed, moreover, is equal to that of the aperture of the diaphragm.

Observations have shown, however, that in order to avoid trouble caused by diffraction, the diameter of the aperture of the diaphragm in a camera 1.6 meters long should be not less than 10 mm. It has been proved by experiments that in order to obtain a sufficient blackening from Jupiter an exposure of 15 minutes is necessary in the photographic area, while in the photovisual area an hour and a half is required; in the case of Saturn the exposure needed is 9 hours and more.

I was able to determine in this way the color index of the sky relative to the Moon and the color index of Saturn relative to Jupiter.

Simple as it may seem, and in spite of its photometrical advantages, this method presents considerable technical difficulties, for it requires very long exposures even with bright stars and planets.

Thinking over the possibility of increasing the illumination on the photographic plate and thus reducing the time of exposure, I arrived at the following idea.

Let us suppose that, in front of the aperture of a camera from which the objective has been removed, there is placed a diaphragm with a small circular prism with a small angle of deflection and placed eccentrically with respect to the camera axis. The base of the prism is oriented towards the camera axis and is situated at such a distance from it as to let the parallel beam, hitting the prism parallel to the camera axis, fall, upon being deflected by the prism, at the centre of the photographic plate.

If n such prisms be arranged around the camera axis, then the illumination at the centre of the photographic plate will be n times as great as that given by a single prism.

*Corresponding member of the Academy.

†*C. R.* (Doklady), *de l'Acad. des Sci. de l'URSS*, 1944, v. XLIV, No. 1.

For adjusting the prisms a small circular aperture with a slide is left in the centre of the diaphragm.

The camera axis is directed towards the Sun which gives a bright circle at the centre of the ground-glass. Hereupon the prisms are rotated in the plane of the diaphragm until the bright circles produced by them become concentric with that formed by the central aperture of the diaphragm.

I made use of two sets of four prisms in each, the angle of deflection being 42′. As should be expected, the exposure was reduced thereby to about one-fourth of the time, so that I was able, in the spring of 1943, to obtain quite a few dozen of both subsidiary negatives and negatives for comparing the brightness and color of Venus and Jupiter.

The observations were carried out with a four-camera coronagraph so that I could take photographs simultaneously in photographic and photovisual rays; this could be attained by using two cameras only.

In this way instead of an image, a certain even blackening is produced. A very important photometric feature of the method described consists in that by rotating the prisms the circles of illumination produced by them can be drawn apart, thus forming areas on which the illuminations are proportional to the figures 1, 2, 3 . . .

The plate-holder is supplied with an insertion-piece movable in front of a rectangular mask, so that several photographs limited by the mask can be taken on a single plate. If for the brighter of the celestial bodies several photographs be taken with different exposures and for the less bright one, a single photograph with a longer duly selected exposure, then such a negative will bear both the scale of luminosity and the time-scale, *i.e.*, all that is necessary for comparing photometrically two celestial bodies.

Even a single-image negative makes it possible to investigate the addition of photographic densities; if some of the prisms are supplied with screens, then it is possible to study the simultaneous photographic action of sources of different color, which has been insufficiently investigated as yet.

Those properties of the method discussed make it extremely valuable for photometric purposes, and scarcely any other method can surpass it. The only condition required by our method is that all the prisms be made of identical material and that they be kept absolutely clean.

Can the number of prisms be augmented? The prisms can be arranged in concentric rings with a centre at the camera axis; but the prisms of every next ring should have a greater angle of deflection, thus giving ever increasing spectra.

This implies certain inconveniences of both theoretical and technical nature. Besides, all the prisms within a given ring should with a rather high degree of accuracy be of an equal angle of deflection.

Much more convenient is the use of small aluminium-coated mirrors, their glass surfaces facing the sky. These may be safely cleansed.*

Every mirror is mounted on a circular plate. By means of one pulling and three pushing collimating screws every plate is attached to a common board. Let us calculate a system of 50 small mirrors which collect light at a distance of 1000 mm. from them. Let the diameter of each separate mirror be 27 mm. Each mirror would then form on the sky a solid angle of 1.88 square degrees. Fifty mirrors would increase the illumination on a photographic plate fifty times, which is equivalent to a luminosity from 94 square degrees; each separate mirror will reflect the light from an equal sky area of 1.88 square degrees.

The total illumination given by all of the fifty mirrors will be 94 times as great as, or exceed by 4.9 magnitudes, that of one square degree of the sky. One square degree of the sky is known, however, to correspond in brilliancy, on the average, to a star of magnitude 4.8.

It is well known, moreover, that the integrated light of the stars constitutes about 1/5 to 1/6 of the total sky-light, made up of the star light and the luminosity of the upper layers of the atmosphere. In other words, the brightness of the night sky is by two stellar magnitudes greater still than that found from the stars alone, which corresponds to no less than one star of magnitude 2.8 per square degree.

Now what will be the efficiency of the 50 mirrors? As shown above, they will augment the brightness by 4.9 stellar magnitudes more; that is, one square degree will yield a light flux equal to that from a star $(2.8 - 4.9) = -2.1$ star magnitude, which approximates the brilliancy of Jupiter at the time of opposition.

As said above, my 1942 observations showed that direct illumination from Jupiter gives quite a sufficient darkening on the negative with an exposure of 15 minutes in photographic and 1.5 hours in photovisual rays. A system of 50 mirrors is thus quite sufficient for studying the brightness and color of the whole sky, not to mention the average sky brightness in the Milky Way, where it is twice as great. Finally, the brightest spots in the Milky Way, for example those in Sagittarius, may be photographed with an exposure of about 5 minutes in photographic, and about 30 minutes in the photovisual rays.

It should be noted that the illumination produced on the plate is absolutely uniform and the measurement is thus reduced to merely determining the density of the blackening on the negative.

We thus obtain an extremely simple and inexpensive instrument, irreproachable in point of theory, for studying the brightness of the sky at any point, applicable to such problems as the average brightness and

*Sets of mirrors up to 210 in number have long since been applied with the purpose of accumulating heat from the Sun by W. J. Buchman, head of the Astronomical Laboratory at the Kazakh State University.

color of the Milky Way at different points, selective light absorption in the dark nebulae of the Milky Way, etc. The only thing necessary is to secure two sets of fifty mirrors each, fixed on the mounting so as to permit the shifting of the one system relative to the other within 30 degrees in declination and by as much in right ascension.

This makes it possible to photograph two spots of the sky simultaneously, for example, a bright area in the Milky Way and a dark nebula.

The Planets in March, 1946

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time, subtract 5 hours, Central Standard Time 6 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will continue to move northward and will cross the equator on March 21 at 5:33 A.M., Greenwich Civil Time. The sun is said to enter Aries at that time, which marks the time of the equinox. Its path does not lie near any particularly bright stars. By the end of the month it will be nearly four degrees north of the equator.

Moon. The phases of the moon will occur as follows:

		d	h
New Moon	March	3	18
First Quarter		10	12
Full Moon		17	19
Last Quarter		25	23

The moon will be nearest to the earth on March 7 and farthest from the earth on March 22.

Mercury. Mercury will begin the month about an hour east of the sun. On March 9 it will reach a point of greatest elongation east of the sun. On and near this date, if conditions are favorable, it may be seen very near the western horizon just after sunset. It will set a few degrees north of the sunset point. After this it will move westward toward the sun and will pass between the sun and the earth on March 26. This position is called inferior conjunction.

Venus. Venus will be east of the sun and will move eastward a little more rapidly than the sun. It will, therefore, set later from evening to evening and thus gradually come into a position which will constitute it the bright evening star.

Mars. Mars will continue in good position for observation. It will be a short distance east of the meridian at sunset. It will continue to recede from the earth and on March 15 its distance from the earth will be about the same as the mean distance of the sun from the earth.

Jupiter. Jupiter will remain about eight degrees south of the equator and will move westward slowly. It will be near a point of opposition with the sun and hence will rise about sunset. Its great brilliancy will serve to distinguish it from the stars.

Saturn. Saturn will remain very nearly stationary in right ascension. It will move slowly westward during the first half of the month and then begin a slow eastward motion. It will remain in the same part of the sky as the planet Mars and with it form an interesting pair of objects for observation and study.

Uranus. Uranus will be in quadrature with the sun, ninety degrees east, on March 4. It will, therefore, be near the meridian at sunset during this period.

Neptune. Neptune, like Saturn, will have a slow retrograde motion. It will be at opposition on March 28.

Asteroid Notes

By HUGH S. RICE

For many weeks no asteroids have been available for observation with small telescopes, but during this year a number of them will be returning to positions where they can be picked up with instrumental aid.

The first one is JUNO. For the present apparition the magnitude is unusually faint, according to the ephemeris, the photo-magnitude for the opposition date being 10.7. According to our observations made at the last apparition, the visual magnitude ran 1.5 brighter than the photo-magnitude; hence if the relation holds true this year we may expect a maximum brightness of about magnitude 9.2 in April at opposition.

According to the ephemeris given herewith, supplied by the Yale University Observatory, Juno appears in mid-February roughly 10° northeast of Spica, and headed in a direction northwest. The visual magnitude then will probably be about 9.7.

In other "Notes" to follow, we shall give further positions of Juno, as well as positions of other planets—IRIS, HERCULINA, VICTORIA, PALLAS, CERES, etc.

EPHEMERIS OF 3 JUNO, FOR 0^h U.T.

1946	α h m	δ ° ′
Feb. 14	14 2.1	−5 50
19	14 2.7	−5 29
24	14 2.7	−5 5
Mar. 1	14 2.1	−4 37
6	14 1.0	−4 7
11	13 59.4	−3 33
16	13 57.2	−2 57

Hayden Planetarium, American Museum of Natural History, New York, N. Y., January 23, 1946.

Occultation Predictions for March, 1946

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phe-

nomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

(Taken from the *American Ephemeris*)

Date 1946	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′									
Mar. 9	148 B.Taur	6.0	2 43.5	0.0	−2.7	125	3 23.7	−0.5	+0.7	211
12	82 Gemi	6.2	23 34.7	−1.8	0.0	108	0 55.1	−2.0	+0.5	263
20	598 B.Virg	6.5	9 40.4	−1.7	−1.1	80	10 40.9	−0.7	−2.6	335
21	6 B.Libr	6.2	6 54.1	−1.9	−0.3	110	8 18.8	−1.5	−1.5	315
	OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′									
Mar. 6	26 Ceti	6.2	0 25.6	−0.6	−0.1	55	1 25.1	−0.3	−0.6	251
12	82 Gemi	6.2	23 5.2	−1.2	+0.6	105	0 18.5	−1.6	−0.6	256
20	598 B.Virg	6.5	9 6.7	−2.0	−1.0	108	10 28.4	−1.3	−2.1	317
21	6 B.Libr	6.2	6 30.3	−0.8	−0.9	146	7 46.6	−2.1	+0.1	281
29	ε Capr	4.7	10 24.6	−0.6	+1.6	76	11 32.8	−1.1	+1.4	261
	OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′									
Mar. 9	163 B.Taur	5.8	5 57.7	−0.5	−0.6	72	6 55.4	0.0	−1.0	267
10	ι Taur	4.7	7 24.0	−0.3	−0.7	75	8 18.6	+0.2	−1.2	278
11	1 Gemi	4.3	7 44.7	0.0	−2.1	124	8 35.3	−0.4	−0.4	243
13	9 Canc	6.2	8 34.1	−1.1	−0.9	83	9 32.1	0.0	−2.0	311
20	598 B.Virg	6.5	8 31.4	−0.3	−2.5	170	9 34.1	−3.1	+0.6	264
22	32 Libr	5.9	8 50.8	−1.3	+0.1	116	10 14.0	−1.6	−0.6	307
23	58 G.Scor	6.4	11 9.4	..	..	36	11 26.7	..	..	13
29	κ Capr	4.8	13 12.3	−1.4	+3.1	23	13 56.4	−1.2	−0.2	309
	OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*									
Mar. 1	χ Capr	5.3	12 20.1	+0.9	−2.8	154	12 43.1	..	..	192
6	26 Ceti	6.2	0 23.9	−1.2	−0.9	86	1 21.8	−0.4	+0.9	217
12	93 B.Gemi	6.8	2 41.8	−2.6	+1.3	62	3 55.4	−1.6	−2.4	308
12	82 Gemi	6.2	22 55.9	−1.6	−1.0	134	23 47.3	−0.7	+3.2	222
13	BD+22°1854	7.2	8 59.6	0.0	−1.1	101	9 35.2	+0.7	−2.1	327
20	598 B.Virg	6.5	9 7.6	−1.7	−1.9	139	10 35.4	−2.0	−1.5	292
22	o Libr	6.1	4 34.6	..	..	44	4 53.0	..	..	10
22	32 Libr	5.9	9 37.0	−3.1	+0.2	90	11 0.7	−1.7	−2.4	330
23	ν Scor	4.3	6 33.8	..	..	44	6 54.6	..	..	9

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U. S. Naval Observatory.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

By this time it is presumed that those of our observers who found time and opportunity to observe during October, especially for the Orionids, during November for the Leonids, and during December for the Geminids, have reported what they did. Among them we are glad to note several new members and we hope that this good start is a promise of real activity for the future. The great majority of our older members are conspicuous by their silence. In some cases, indeed, it is known that plans were ruined by clouds, in a few by illness, and of

course many of the most active male members are still in military service. For these, I fear, scientific initiative is not too much encouraged by some higher officers, even when local conditions would give the individual opportunity to observe. However, the record of what was accomplished follows, the data being arranged as usual. Perhaps it is well to repeat that we use the old astronomical day which starts at noon, not the civil date. Remarks will follow.

Observer and Station	Date 1945 m	d	Began h	m	Ended h	m	Min.	s →	Fac.	Unc. R.	Ob.	C
Hukill, R. M., Wilmington, Del.	10	18	14	:00	16	:00	120	20	0.4	10	1	P
" "	12	12	14	:00	16	:00	120	17	1.0	8	1	P
Sandmeyer, Miss E., Buhl, Idaho	10	18	17	:10	17	:40	30	14	1.0	28	1	C
Hay, A. A., Chicago, Ill.	10	29	9	:48	11	:	72	3	1.0	2	1	P
" "		30	9	:00	11	:00	120	4	0.7	2	1	P
" "	11	1	8	:30	10	:30	120	1	0.3	..	1	P
" "		3	15	:30	17	:30	120	5	1.0	2	1	P
" "		5	9	:30	11	:30	120	10	1.0	5	1	P
" "		10	9	:30	10	:25	55	2	0.7	2	1	P
Fitzsimmons, C. S., Sibley, Iowa	12	6	10	:34	12	:20	106	20	1.0	11	1	P
Dole, R. M., Cape Elizabeth, Maine	10	8	9	:10	10	:00	50	11	1.0	13	1	P
" "		9	9	:00	10	:00	60	9	1.0	9	1	P
" "		19	16	:00	16	:15	15	3	0.3	..	1	P
" "	11	15	15	:00	15	:30	30	4	0.5	8	1	P
" "	12	11	12	:00	15	:00	180	66	1.0	22	1	P
" "		12	13	:00	17	:00	240	343	1.0	86	1	P
" "		14	16	:00	17	:00	60	0	0.9	0	1	P
" "		16	16	:30	17	:30	60	16	0.9	16	1	P
Skinner, G. B., Brockton, Mass.	10	18	9	:00	11	:15	125	0	0.6	0	1	
" "		19	9	:00	11	:45	165	1	0.6	1	1	P
" "		20	9	:00	10	:45	105	0	0.5	0	1	
Pillans, Miss H., So. Hadley, Mass.	10	9	10	:00	12	:00	120	26	1.0	13	1	P
" "		27	10	:00	13	:00	180	31	0.6	10	1	P
Vanden Norte, Miss. V., S. Hadley, Mass.	9		10	:00	12	:00	120	26	1.0	13	1	P
" "		27	10	:00	13	:00	180	31	0.6	10	1	P
Scharlach, W. W., Columbus, Ohio	10	12	8	:50	9	:45	55	2	1.0	2	1	P
Gorson, R. O., U.S.A., Ocean, $\lambda = 178°$ E, $\phi = 32°$ N	10	15	11	:30	15	:30	240	48	0.7	..	2	P
Oravec, E. G., New York, N. Y.	10	18	16	:15	17	:05	50	3	0.6	4	1	P
" "		20	12	:30	16	:00	210	15	0.4	4	1	P
" "	12	11	8	:35	10	:12	55	4	0.7	4	1	P
" "		12	9	:25	10	:10	45	2	0.6	3	1	P
Stowe, B., Yonkers, N. Y.	10	20	12	:30	16	:00	210	13	0.4	4	1	P
Waldman, E. G., Bronx, N. Y.	10	1	12	:02	12	:52	50	3	1.0	4	1	P
" "		2	12	:20	13	:20	60	8	1.0	8	1	P
" "		3	12	:08	13	:08	60	4	1.0	4	1	P
" "		13	14	:47	15	:47	60	8	0.9	8	1	P
Cole, Mrs. R. M., Bryn Athyn, Pa.	11	16	11	:30	12	:30	60	5	0.3	..	g	P
Liss, A., Hunting Park, Pa.	9	12	9	:30	11	:15	145	24	1.0	10	1	D
" "	10	28	10	:00	11	:45	105	3	1.0	2	1	D
Olivier, C. P., Flower Obs., Pa.	11	15	15	:07	16	:07	60	6	0.9	6	1	P
Shutts, R. V., North Hills, Pa.	10	27	12	:10	14	:10	120	28	0.6	..	3	P

The most striking observations are those for Dec. 12/13 by R. M. Dole. This observer has had over 45 years of active meteor work to his credit, and, in mentioning the unusual features of his report, I shall quote from it directly only using my own words to make clear what the maps show, since we cannot well reproduce them here. On the date in question he worked from 13^h to 17^h, the night being "exceptional, brilliantly clear, bitterly cold." (Cape Elizabeth, his station, is on the Main coast not far from Portland.) Dole condenses his reports so that he gets two meteors on each line, but even at that it covered 6¼ record sheets

for the 343 meteors. The first sheet runs from 13:00 to 13:55± and has 56 meteors. At top of second sheet: "Rapidly moving curtain of meteors moved NE from $\delta = +12°$ to $+20°$, $\alpha = 14^h$, meteors very, very short, about 3 mag., often parallel." On third sheet: "Meteors straight down, all in E and SE, many queer curves, very short as if head-on, radiant apparently moved rapidly N and E." On fourth sheet: "Constellations rose and passed westward, but meteors heavily concentrated in a narrow band which moved as noted $\delta = +12°$ to $\delta = +20°$, $\alpha = 15^h$." On fifth sheet: "Very few meteors in area S-SW-W (none observed in W-NW-N) only about four seen in NE, all brilliant." On sixth sheet: "Leonids distinct branch of this shower also center Quadrans — also center, below Gemini." In sheet seven: "1 hour observing to W yields only a few. Because bitter W wind, temp. 3°, watch was concentrated S-NE." On map ". . . practically no 6th mag., very few 5th mag., mostly 3rd . . ."

Six AMS maps were submitted, IV, V, 2 of X, 2 of XI. On three of these maps the general pattern of plotted paths was about as usual, but on the three others the plots are different from what the writer has ever seen, or, I believe, read of. For instance on Map V, Arcturus is roughly the center of not less than 100 paths coming from the general direction of Gemini, but only 1° to 2° long, forming literally a "curtain" of plots. As these are from 5h to 7h distant in right ascension from the Geminid radiant, how could real Geminids have such short paths in this area? Could they have been Geminids at all? Again on Map X, with Regulus roughly as center, a similar "curtain" is plotted. And on Map XI another "curtain" between Arcturus and Spica, all meteors 1° to 3° long only, according to the plots.

I have gone to considerable lengths in describing this most unusual report though, having done do, I cannot pass upon something wholly out of my own experience by explaining how the meteors could be so concentrated and so short. But as Dole is, in terms of service, one of the oldest meteor observers living, and has had very wide experience, I would be unjust to him not to put this fully upon record so that it can be discussed by other competent authorities, and perhaps encourage others to report who may have seen something similar. As for general remarks on the three showers, the Leonids seem wretchedly poor, the Orionids were too interfered with by moonlight for definite opinions to be expressed, while the Geminids (but for Dole's report) would be classed as fairly active. These remarks, being based only upon the tabular data above, are liable to revision should more observations come in.

It will greatly interest the A.M.S. to learn that through one of our members in the U. S. Army of Occupation in Japan, I have just received the report of what was done in that country on meteors from January, 1942, to July, 1945. It is by Koziro Komaki, President of the Meteor Section O.A.A., who himself was a member of our Society when the war broke out and quite an active one. Indeed we then had several Japanese members, some of whom did excellent work. As I believe that the peace of the world can best be served by universal scientific cooperation, particularly in such subjects as astronomy, I hope that some proper means will soon be devised for permitting citizens of late-enemy countries to resume cultural relations, at least those who were not personnally war criminals. In our next Notes I hope to briefly review the data and results in the publication just mentioned.

Flower Observatory, Upper Darby, Pennsylvania, 1946 January 21.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

On the Ownership of Recovered Meteorites

LINCOLN LA PAZ
Institute of Meteoritics, University of New Mexico, Albuquerque

ABSTRACT

Roy R. Carpenter's digest of the legal cases where the ownership of a recovered meteorite was the subject of controversy is reviewed. The accepted ruling as to the ownership of recovered meteorites is shown to be unreasonable and to work against the best interests of science. It is urged that such organizations as the Society for Research on Meteorites seek to secure more just and realistic legislation on this highly important question.

Roy R. Carpenter has recently published in these CONTRIBUTIONS[1] an interesting digest of rulings on the ownership of recovered meteorites, based on "a careful and quite exhaustive search" thru the indices of standard legal reference works and the various court-reporter systems of the United States. His findings may be briefly summarized as follows:

(1) The earliest case of which we have record, in which a recovered meteorite was the subject of controversy, arose in France and dates from 1842 September. In this case, the aerolite was adjudged by M. Duranton to belong to the finder and not to the owner of the field in which it fell. Specifically, it was ruled that "*a stone fallen from the heavens cannot be an accession of the land upon which it alights; it belongs entirely by occupation to him who has found it.*" Marcadé, in reviewing this case, states that he "can hardly conceive how an advocate could have been found to entertain the contrary opinion."

(2) However, since the French case of 1842, one French and two American courts have concurred in the following ruling in regard to the ownership of recovered meteorites: *A recovered meteorite is not the property of the finder but belongs to the owner of the land upon which it fell.*

It is the purpose of this communication to attack the latter ruling cited, from two angles: (*a*), on the one hand, it will be shown that the so-called reasons cited by the courts as justification for the ruling in question are irrational; and (*b*), on the other hand, it will be pointed out that the decision as to ownership now accepted is prejudicial to the best interests of science and to public morality.

As regards (*a*), we note first that the "Law of Accretion" is the chief mainstay of those who defend the ruling (2). But "accretion" as understood in law relates to processes which increase accumulations of one sort or another in or upon one portion of the Earth's surface *at the expense* of another portion (see the typical examples quoted by Carpenter). The falling of a meteorite upon the Earth bears not the slightest resemblance to these ordinary processes of accretion. A meteorite fall does not transfer anything to *A*'s land at the expense of *B*'s land,

as is the case when wind or water removes soil from one man's field and redeposits it in the field of another. Yet we find the justice who adjudicated the famous Iowa case of John Goddard *vs.* H. V. Winchell asserting that it is not easy to understand why meteorites fallen from heaven should be governed by a different rule from that which obtains for deposits of common terrestrial boulders and stones filched by "glacial action" from one portion of the Earth's surface and redeposited on another![2] A meteorite fall robs no part of the Earth's domain, but, instead, enriches the common clay with a celestial treasure; and, as a treasure, the question of its ownership should be decided on the basis of one of the oldest laws, the Roman Law XXX, pertaining to the division of treasure between the finder and the owner of the land whereupon the treasure was found. Again, in defense of the ruling (2), it has been asserted that the relation of a meteorite to the soil onto or into which it falls is the same as that of a mineral deposit occurring in that soil. Such a contention verges on the absurd. A mineral deposit is "a geologic body."[3] Mineral deposits evolve from the Earth itself. They are, at every stage of their development, of the Earth, earthy. On the contrary, whatever the origin and the history of the meteorites (and much remains to be decided on these matters), these bodies have certainly no genetic connection with the Earth. They are, *par excellence,* examples of "such things as are not naturally parts of the Earth or sea." Yet the Iowa justice who defined "movables" in the words just quoted refused to permit the application of Blackstone's ruling on the ownership of "movables" to the aerolite which was the subject of controversy in his court! It would be difficult to find a better illustration of unreason in the extensive literature of The Law. Moreover, not only are mineral deposits, *i.e.,* "local accumulations or concentrations of useful metals," derived from the rocks of the Earth's crust,[4] and, therefore, quite different *in origin* from the meteorites, but the processes by which mineral deposits are formed—*e.g.,* solvent action, magmatic differentiation, weathering — bear not the remotest resemblance to the process by which a meteorite becomes associated with the soil of this globe. Even the confused Iowa justice perceived this essential fact, since, for the Winnebago County aerolite, he conceded that "Except for the peculiar manner in which it came, its relation to the soil would be beyond dispute." This concession, and the illusory and illogical nature of his other arguments, leave his labored opinion without one leg to stand on; and he gives further evidence of his incapacity by making the ridiculous assertion that the aerolite in question has "nothing in its material composition to make it foreign or unnatural to the soil." He might equally well have contended that an iron filing is neither foreign nor unnatural in an eyeball; yet the opinion he based on absurdities of this sort was felt "to subserve the ends of substantial justice" and has been accepted by other courts as setting a precedent!

In support of our contention (*b*), we need point out only that the actual effect of the ruling (2), accepted at present in regard to the ownership of recovered meteorites, is all too frequently the following: Either those fortunate enough to witness a meteoritic fall refrain from searching for and finding the fallen meteorites because they are aware that the law allows them no equity in these objects or, in case they do search for and find meteorites, they either conceal the fact of the discovery of such masses, thereby again robbing the science of meteoritics of information and specimens of great value, or they falsify their accounts of the recovery of the meteorites in order to conceal the true places of find. In this wise,

incomplete or untrustworthy data come into the literature of science, and the weight of falsehood descends onto the shoulders of those very individuals who were lucky enough to see a meteorite fall and who had the initiative and perseverance to bring about its recovery.

It is useless to argue that, because certain unfortunate precedents exist for the ruling (2), criticized previously, this ruling must be accepted as inevitable everywhere and for all time to come. Actually, the digest given by Carpenter shows that, at least since 1842 (and possibly in a cogent sense since the time of the establishment of the Roman Law XXX), there has existed a precedent for a much fairer and more realistic ruling on the ownership of recovered meteorites. Furthermore, whatever the absurdities that the unscientific reasoning of some jurists occasionally foists upon the public, one cannot deny that, once a law has been shown to be either ridiculous, or bad, or both, the courts are among the first to sanction and, indeed, to force its revision. With this fact before us, it would seem well for such organizations as the Society for Research on Meteorites to go on record before the courts as condemning the ruling (2) quoted earlier in this paper.

Finally, since the present rapid growth of interest in the recovery of meteorites will inevitably lead to controversies concerning ownership in all parts of the United States, steps should be taken for the establishment in those States, where no ruling on the ownership of recovered meteorites has as yet been made, of a ruling at least as just and as well-founded as the Roman Law XXX. It is well to note in this connection that precisely such a division of recovered treasure as is envisaged in that old Roman Law is the one habitually agreed on by the owner of the land to be searched and the professional meteorite hunter, *before* a search for meteorites is begun. This fact is in itself proof that, *before* discovery, even the most greedy, unreasonable landowner recognizes that those who are *able* to find meteorites deserve a half equity in their recoveries. It is curious that, *after* discovery, the landowner's selfish claim to *all* of the meteoritic material found has received the sanction of supposedly unbiased Justice!

References

[1] Carpenter, R. R., *C.S.R.M.*, **3**, 189-98; *P.A.*, **53**, 186-92, and 238-41, 1945.
[2] Carpenter, R. R., *loc. cit.*, *C.S.R.M.*, pp. 192-3, and *P.A.*, p. 190.
[3] Emmons, W. H., *The Principles of Economic Geology* (McGraw-Hill, New York), 2nd Ed., 1, 1940.
[4] Lindgren, W., *Mineral Deposits* (McGraw-Hill, New York), 3rd Ed., 11, 1928.

A Remark on the Puente-Ladron, New Mexico, Aerolite

Lincoln La Paz
Institute of Meteoritics, University of New Mexico, Albuquerque

ABSTRACT

There is ample evidence to support the belief that the American Indians collected meteorites and preserved them for longer or shorter periods, during which, in some cases, the meteorites were transported over considerable distances. The strip of country along the Rio Puerco, within which the Puente-Ladron, New Mexico, aerolite was found, was one of the main highways of Amerind traffic and a favorite camping and hunting ground until very recent times. Unless it can be shown that the aerolite in question was not transported into this area by

an Indian and there discarded or lost, an all-out search of the Puente-Ladron area for other members of the shower to which it has been conjectured the stone belongs does not seem justified.

The recovery of a 7.7-gram aerolite (named Puente-Ladron, Socorro County, New Mexico; coördinate number = 1068,344), near the intersection of U. S. Highway No. 85 and the Rio Puerco, has recently been described in minute detail.[1] The description is accompanied by an appeal to all meteoriticists to coöperate in a search for other members of the shower to which the aerolite is assumed to belong. Because of the small size of the recovered specimen, it is most probable that, in case it was a member of a shower, it fell at the extreme *end* of the *unknown* strewn field. The area which may have to be searched is therefore the maximum possible under the circumstances and is admitted to amount to many square miles. This communication is written to point out that actually the situation may be even less favorable than has just been indicated, so that an area of several hundred square miles or more may have to be searched before other members of the problematical fall are found.

Attention has been directed to the occurrence of numerous Amerind artifacts in the surface drift near the point of recovery of the Puente-Ladron aerolite.[2] I was therefore led to inquire of experts in the archeology of the Southwest as to whether or not the area in which Puente-Ladron was found might not have been a favorite gathering place of the Indians. Professors W. W. Hill and Paul Reiter of the Department of Anthropology of the University of New Mexico assure me that this was indeed the case. Along the Rio Puerco and other New Mexico rivers most of the flow of Amerind traffic was concentrated. Numerous ruins assignable to the Socorro Black and White culture occur along or near the Rio Puerco, and its environs in the Puente-Ladron area were obviously a favorite camping and hunting ground of the Pueblo builders. According to Bandelier, descendants of the original Pueblo builders were encountered in this neighborhood as late as 1879. In view of these facts and the well-known propensity of the Amerinds to collect and preserve meteorites for longer or shorter periods,[3] it is clear that we must not overlook the possibility that the Puente-Ladron aerolite was picked up by an Indian and carried into the strip along the Rio Puerco, where the meteorite was either discarded or lost. If such were indeed the case, the actual point of fall of the aerolite may have been scores, or even hundreds,[4] of miles from the spot where it was again recovered in 1944. Unless this possibility can be excluded—unless, in short, the "meteoritical position problem"[5] associated with the Puente-Ladron recovery can be solved—there would seem to be little justification for conducting an all-out search in the Puente-Ladron neighborhood.

REFERENCES

[1] Nininger, H. H., *C.S.R.M.*, **3**, 165-7; *P.A.*, **52**, 407-10, 1944.
[2] Nininger, H. H., *loc. cit.*, *C.S.R.M.*, p. 167, and *P.A.*, p. 410.
[3] Nininger, H. H., *Am. Antiquity*, **4**, 39-40, 1938.
[4] Kunz, G. F., *Am. Jour. Sci.*, 3rd Ser., **40**, 312-23, 1890.
[5] *Cf.* La Paz, L., *C.S.R.M.*, **3**, 148-53; *P.A.*, **52**, 300-6, 1944.

The Zodiacal Light and Meteorites

The following excerpt is taken from the Revised (1945) Edition of Russell, Dugan, and Stewart's "*Astronomy*," **1**, §§ 424 and 424*a*, pp. 359-60:

"The observations make it almost certain that the zodiacal light is *reflected*

sunlight from innumerable small bodies, scattered thruout a region shaped like a lens or a much flattened ellipsoid of revolution, having its greatest diameter nearly in the plane of the ecliptic and extending well beyond the orbit of the Earth. The light is of the color of sunlight (as shown by observations with color screens) and is very little polarized—showing that the bodies are *not* [italics mine] gas molecules or very fine dust.

"The quantity of reflecting matter necessary to produce the observed illumination of the sky is surprisingly small. Calculation shows that it would be accounted for if, inside the Earth's orbit, there were particles 1 millimeter in diameter, of the low albedo of the Moon, and 5 miles apart; or bodies 10 feet in diameter and 1,000 miles apart. On the second assumption, the aggregate mass of the particles within a sphere of diameter equal to the Earth's orbit would be less than 1/40,000 of the Earth's mass—far too small to produce any sensible effect upon the motions of the planets by its attraction. On the first assumption, the total mass is only 1/3,000 as great. There is good reason to suppose that such small particles are absent.

"Poynting (in 1903) showed by approximate reasoning, and Robertson (in 1937) proved, that a body revolving about the Sun, receiving heat from it, and radiating this again into space, will undergo a gradual diminution of its mean distance, so that it will move in a slowly contracting spiral and ultimately fall into the Sun. The time required, in millions of years, is $7a\rho R^2$, where a is the body's radius in centimeters, ρ its density in g./cm.,[3] and R its initial distance in astronomical units. A ball of rock of radius 1 cm. would go in from the Earth's distance in 20 million years. In the past 2,000 million years [the estimated age of the Earth and of fallen meteorites], the region of the zodiacal light should thus have been swept clear of all small bodies."

The inescapable conclusion from the preceding discussion is that the zodiacal light is due to the reflection of sunlight by countless widely dispersed interplanetary meteorites of considerable size.—F.C.L.

President of the Society: LINCOLN LA PAZ, Department of Mathematics and Institute of Meteoritics, University of New Mexico, Albuquerque

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, P. O. Box 9865, Los Feliz Station, Los Angeles 27, California

---

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

The A.A.V.S.O. Million Mark: Since late in the year 1911 the A.A.V.S.O. has been accumulating observations of variable stars, especially on the long-periods and irregulars of the R Coronae Borealis and SS Cygni types, and the novae which become brilliantly visible to the unaided eye.

At the close of the year 1945 more than 987,000 observations had been made and contributed to the headquarters, and there is every prospect that before the first half of 1946 has gone the million mark will have been reached.

Over 1,000 individuals have taken part in this observing program, some with

only a few desultory observations over a few months or years, others with many thousands over many years. That this progress toward the first million mark has not been uniform is shown by the curve in the accompanying figure, which represents the steady annual march from late in 1911 to the close of 1945. Also shown on the figure (Figure 1) are the names of several bright novae which

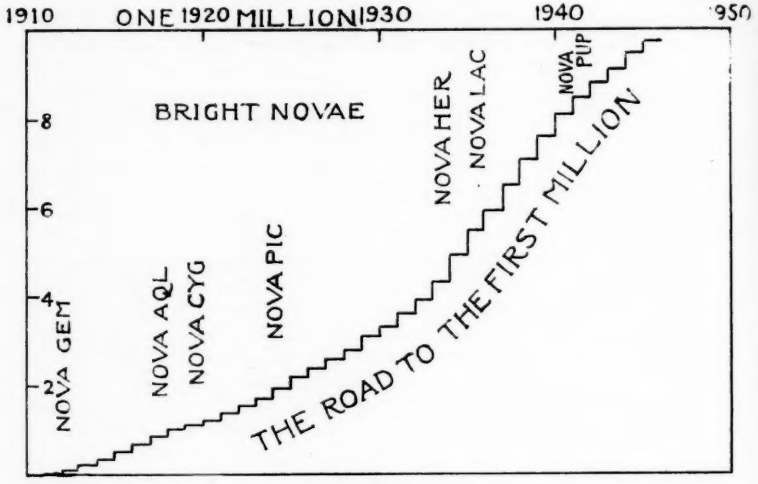


FIGURE 1

have been very assiduously observed during these same years by the many contributors.

Light Curve of R Coronae Borealis in 1945: The light variations of R Coronae Borealis during 1945 have been most interesting. At the beginning of the year the variable was at normal maximum brightness, sixth magnitude. About February 15 it began to fade away to what seemed at first to be a reasonably faint minimum, but a month later it had reached only to magnitude 7.6, where it

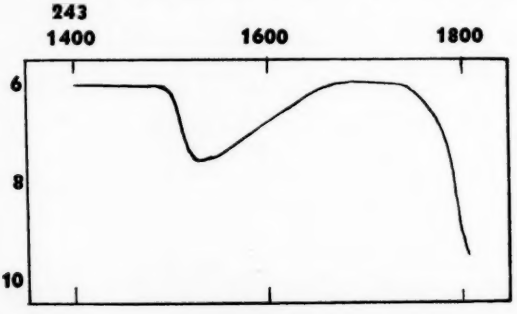


FIGURE 2
LIGHT CURVE OF R CORONAE BOREALIS IN 1945

remained for a short time, then began a steady and uniform rise to maximum, which was attained early in August. About October 20 the star started again on the downward grade, and by December 15 had reached magnitude 9.5. According to the latest report, the variable has again increased in brightness to magnitude 7.1 on January 7, 1946.

The star is very unfavorably placed for observation at this season, but it is hoped that observers will continue to follow the star, which is now better seen in the morning sky.

The accompanying figure (Figure 2) illustrates the activities of the star during the year 1945.

Predicted Maxima of Bright Long-Period Variables, 1946: Listed herewith are predicted dates of maxima for long-period variables, which, on the average, are brighter than the 8th magnitude at maximum. In the successive columns are given the designation number and name of each variable, the month and day in 1946 of the predicted maximum, and in the last column the mean maximum magnitude, recently deduced from a discussion of nearly 400 long-period variables. A recent A.A.V.S.O. Bi-monthly Bulletin containing a list of predicted dates of maximum and minimum for 1946 may be secured, while available, by addressing the A.A.V.S.O. Recorder, Harvard Observatory, Cambridge 38, Mass.

MAXIMA OF BRIGHT LONG-PERIOD VARIABLES FOR 1946

Brighter than 8.0 magnitude

Design	Name	Date of Max. m	d	Max. Mag.
001032	S Scl	1	3	6.8
001755	T Cas	10	6	7.8
001838	R And	10	18	7.0
021143a	W And	8	26	7.5
021403	*o* Cet	11	26	3.7
022813	U Cet	8	12	7.5
023133	R Tri	3	6	6.3
		11	27	
025050	R Hor	11	27	6.0
043263	R Ret	5	23	7.7
045514	R Lep	9	23	6.7
051533	T Col	6	3	7.6
054920a	U Ori	1	17	6.6
055686	R Oct	2	4	7.9
061702	V Mon	4	8	7.1
065208	X Mon	3	8	7.6
		8	11	
065355	R Lyn	4	9	7.9
070122a	R Gem	2	8	7.1
072708	S CMi	3	6	7.5
072820b	Z Pup	3	12	7.9
081112	R Cnc	5	10	6.8
082405	RT Hya	2	1	7.6
		10	15	
084803	S Hya	6	17	7.9
085008	T Hya	9	5	7.7
092962	R Car	10	21	4.6
093934	R LMi	9	26	7.2
094211	R Leo	7	29	5.9
100661	S Car	5	20	5.7
		10	16	
103769	R UMa	7	10	7.6
114441	X Cen	4	4	7.8
121418	R Crv	7	16	7.6
122001	SS Vir	2	19	6.9
123160	T UMa	9	4	7.9
123307	R Vir	1	4	6.9
		5	29	
		10	21	
123961	S UMa	6	28	7.9
132422	R Hya	5	4	4.6
132706	S Vir	3	12	7.1
133633	T Cen	2	2	6.1
		5	4	
		8	3	
		11	2	
134440a	R CVn	9	9	7.7
140959	R Cen	3	17	5.9
142539	V Boo	4	28	7.9
143227	R Boo	7	12	7.3
151731	S CrB	8	28	7.5
151822	RS Lib	3	13	7.7
		10	17	
152849	R Nor	3	17	7.2
153654	T Nor	7	6	7.4
154615	R Ser	8	4	6.8
154639	V CrB	6	6	7.4
162112	V Oph	6	16	7.5
162119	U Her	6	2	7.6
163266	R Dra	6	18	7.6
164715	S Her	1	10	7.6
		11	13	
164844	RS Sco	3	10	6.8
165030a	RR Sco	7	9	6.0
		12	9	
170215	R Oph	2	10	7.6

Design	Name	Date of Max. m	d	Max. Mag.
182133	RV Sgr	3	8	7.8
183308	X Oph	11	10	6.9
190108	R Aql	8	27	6.3
191019	R Sgr	9	11	7.2
193449	R Cyg	12	27	7.3
194048	RT Cyg	2	10	7.4
		8	19	
194632	χ Cyg	5	4	5.3
194659	S Pav	6	25	7.3
194929	RR Sgr	9	21	6.6
195142	RU Sgr	8	8	7.2
200938	RS Cyg	2	4	7.4
201139	RT Sgr	6	20	7.9
201647	U Cyg	5	21	7.6
204405	T Aqr	1	16	7.9
		8	6	
210868	T Cep	2	28	5.8
221948	S Gru	12	7	7.8
230110	R Peg	1	17	7.9
230759	V Cas	4	4	7.9
233815	R Aqr	6	22	7.3
235150	R Phe	5	13	7.8
235350	R Cas	7	18	6.5

Observations for November and December: A total of 5,564 observations—2,961 in November and 2,603 in December—were contributed by 52 observers, as listed herewith.

Observer	November—1945—December No. Var.	No. Ests.	No. Var.	No. Ests.
Ashbrook	...	...	2	2
Bappu, M. K. V.	18	96	...	...
Blunck	48	55	21	21
Boone	28	28	12	12
Bouton	33	48	13	16
Braitberg	5	22	4	11
Buckstaff	15	26	12	15
Chabot	...	...	2	20
Cilley	21	25	...	...
Cousins	...	...	66	121
Cragg	...	...	48	54
Dafter	5	14	...	...
Duffie	34	62	30	44
Fernald	246	396	309	633
Garneau	17	18	21	22
Gemberling	50	50	...	...
Harris	31	31	80	82
Hartmann	182	203	175	191
Holt	120	281	...	...
Houston	32	66	...	...
Howarth	14	14	16	16
Hukill	3	24	6	44
Irland	26	33	12	13
Kearons	63	80	...	...
Kelly, F. J.	13	18	...	...
Kelly, K.	...	...	10	25
de Kock	82	345	81	356
Koons	19	32	...	...
Kitley	...	...	17	38
Mary	13	13	40	40
Mount	7	18	...	...
Nadeau	18	19	71	71
O'Byrne	14	43	10	21
Oheim	115	140	107	111
Oravec	23	90	25	95
Parks	20	34	19	19
Peltier	127	179	81	113
Petzold	...	...	7	24
Rayna	...	...	2	22
Reeves	2	3	1	3
Renner	45	45	36	45
Rosebrugh	17	126	16	90
Segers	10	25	16	23
Sill	...	...	23	24
Stahr	3	4	8	29
Stowe	18	26	...	...
Taboada	29	29	35	35
Topham	63	64	24	27
Webb	13	15	14	14
Weber	15	25	40	40
Welker	10	16	8	9
Zirin	...	...	10	12
52	Totals	2,961		2,603

January 15, 1946.

Comet Notes

By G. VAN BIESBROECK

New Comet du Toit. From the Boyden Station of the Harvard Observatory in Bloemfontein (South Africa) has come the report of the discovery of an unexpected comet by D. du Toit in December. The following information was cabled:

1945 December 11, Right ascension $15^h\,8^m$, Declination 65°, Magnitude 7. Daily motion 30 minutes east and 1° 13′ north.

This is the third comet discovered this year by this active observer, a most unusual record. The rapid motion points to a short distance from the earth at the time of discovery. Since the motion was in the direction of the sun the object may have soon been lost in the daylight. Up to this time, a month after discovery, no further information has been received about it.

COMET FRIEND-PELTIER, whose discovery on November 22 was mentioned last month, has apparently not been seen again on account of its nearness to the sun. From his preliminary orbit, L. E. Cunningham has computed a backward ephemeris, in the hope that the image of the comet might be located on prediscovery photographic exposures, as follows:

1945		α h m	δ ° ′	Mag.	Mag.
Sept.	22	1 49	83 35	13.4	15.8
	30	22 36	87 30	12.9	15.1
Oct.	8	17 15	84 22	12.3	14.4
	16	16 29	78 3	11.7	13.6
	24	18	70 39	11.1	12.7
Nov.	1	17	62 5	10.3	11.7
	9	17	52 7	9.5	10.6
	17	18	40 21	8.5	9.2
	25	16 19	26 11	7.4	7.6

In the last two columns are given the hypothetical magnitudes computed under the assumptions that the brightness varies as the fourth or the sixth power of the distance from the sun. The location was favorable for an early discovery. If the earlier presence could hereby be established it would be possible to make a better prediction of the later course. All through the first four months of the year the comet will remain hidden in the sun's rays and, when it finally emerges in May, the brightness will be so reduced and the exact location so uncertain that further observations are doubtful.

There is some inconsistency in the designation of this comet: Circular 1023 of the International Astronomical Union calls it 1945 *f* while *Announcement Card* 731 of the Harvard College Observatory designates it as 1945 *e*. The discrepancy results evidently from the inclusion of comets found last year and still followed this year.

Further observations were obtained on the periodic comets that had been followed earlier in 1945.

PERIODIC COMET KOPFF was last recorded by the writer on January 2 as a fuzzy nucleus followed by a broad tail in position angle 70°. The total magnitude was reduced to 15 and since the comet moves gradually into the evening twilight it will probably not be followed further. It has been under observation for nearly eight months.

PERIODIC COMET VÄISÄLÄ had changed very little from its previous aspect when last recorded here January 2. The total magnitude was then 16.5 and the appearance was that of a hazy spot about 10″ in diameter and centrally condensed. This object too is being lost now in the evening sky.

PERIODIC COMET SCHWASSMANN-WACHMANN has again exhibited unexpected changes in appearance. We reported it as an almost stellar image of magnitude 18 early in December. When it was recorded anew on January 1 it had brightened up to magnitude 16 and showed besides a sharp nucleus, a fairly bright coma spreading out in a broad, fan-shaped tail between position angle 40° and 160°. The tail

was about 40″ long and there was hardly any coma visible in the remainder of the circle around the nucleus. The next day the same appearance prevailed but already appreciably fainter.

Thus the unexplained instability which has characterized this object still manifests itself and its continued observation is most desirable.

McDonald Observatory, Fort Davis, Texas, January 11, 1946.

General Notes

Dr. Hans Fried died suddenly at his home in Lansdowne, on December 23, 1945, at the age of 52. Born in Vienna, Austria, he studied at the University of Vienna and obtained his doctor's degree in mathematics in 1923. After a teaching career he left Vienna in June, 1939, for England, and arrived in the United States of America in 1940. From September, 1941, till November, 1943, he was assistant in the Sproul Observatory, taking part in the measuring, reducing, and discussion of photographic plates; from July, 1944, on he was lecturer in mathematics at Swarthmore College.

Dr. Harlow Shapley, Director of the Harvard College Observatory and National President of the Society of the Sigma Xi, spoke at the University of California, Los Angeles, on the afternoon of December 7, 1945, on the subject of "Planetary Perplexities." On the evening of December 8, Dr. Shapley delivered the final address of a two-day "Conference on American-Russian Cultural Exchange," sponsored at the University jointly by Phi Beta Kappa and Sigma Xi. The latter address, at which Dr. Robert A. Millikan of the California Institute of Technology presided, was entitled "Planetary Worries, Science, and Peace."

The Rittenhouse Astronomical Society held its monthly meeting on January 11, 1946, at the Randal Morgan Physics Laboratory, University of Pennsylvania. Mr. A. Clyde Schock of the Central High School of Philadelphia spoke on the topic "Philadelphia Astronomers of the Past."

Société Astronomique de France. Under the date of November 30, 1945, the treasurer of the Société de France announced to its members that the Société would again resume its activities as before the war. All such enterprises necessarily came to a standstill during the war. It is reassuring to learn that France has now returned so far toward the former conditions as to make possible the resumption of pre-war programs.

National Capital Astronomers

On January 5 the National Capital Amateur Astronomers Association streamlined its name, adopted a constitution, and amended the by-laws. Junior membership was established with no minimum age and, judging from the immediate applications, interest is spreading rapidly among the younger set.

Initiation fee was abolished; dues for regular members remain $3 a year. More specific functions were assigned to the Board of Trustees.

The name and address of the secretary for 1945-46 are Mrs. Wm. P. Harris, Jr., 4315 Chesapeake Street, N.W., Washington, D. C.

The Cleveland Astronomical Society

Dr. C. K. Seyfert of the Warner and Swasey Observatory, Cleveland, Ohio, lectured on "The Great Spiral Nebula in Andromeda" at the January 18 meeting of the Cleveland Astronomical Society.

The speaker oriented the audience with respect to distances and sizes by pretending to split a spider thread twenty times until he had a piece only one twentieth the diameter of the original. A piece four one-millionth of an inch long was cut from this and the edges trimmed off to make a sphere. This he placed on the table to represent the earth. On the same scale the solar system could be represented by a circle four inches in diameter. The nearest star would be 1000 feet away and the visible portion of our galaxy would be approximately the size of Ohio in plan with the whole galaxy occupying the United States.

The scattered dust particles in our galactic system limit the distance to which it can be explored. It was explained that the size and shape of our system has been determined largely by the distribution of the globular clusters. When the line of sight is somewhere near perpendicular to the plane of our galaxy only a small amount of dust is encountered. Other galactic systems in these directions may thus be studied to better advantage than our own.

The speaker selected the Andromeda Nebula for study. It has about the same diameter as our galaxy, namely 100,000 light years and in many ways is a twin to our system. It is approximately 700,000 light years distant. Its plane is tilted at a favorable angle so that the spiral arms are visible and radial velocities may be determined. With a well prepared model the speaker demonstrated how the direction of rotation of a spiral nebula may be determined and showed that in the case of the Andromeda Nebula the arms are trailing and the spiral is winding up.

The enthusiasm and clearness of the speaker were reflected in the attentive and interested audience.

HENRY F. DONNER.

Western Reserve University, Cleveland 6, Ohio.

Meeting of the Midwest Group of Astronomers

On January 12, at the Yerkes Observatory, there took place an informal meeting of astronomers of the Midwest. As in previous years, a number of scientific papers of considerable interest were presented. After a luncheon, Dr. Veining Meinesz, the Dutch geophysicist who is now visiting this country as Scientific Delegate of the Netherlands Government, described the conditions of university life in Holland under the Nazi regime. The repressive acts of the Nazis drove the entire student body into underground activities, in which the faculties also took part.

The scientific program of the meeting follows: JOEL STEBBINS and A. E. WHITFORD: The relation between color and absolute magnitude in G and K stars. S. CHANDRASEKHAR: The identification of H-minus in the sun. GUIDO MUNCH: A theoretical interpretation of the six-color photometry of Stebbins and Whitford. C. M. HUFFER: The orbital eccentricities of eclipsing binaries. W. A. HILTNER: Some interesting spectroscopic binary systems. W. W. MORGAN and S. SHARPLESS: A remarkable emission line star. A. J. DEUTSCH: The spectrum variable, ι Cassiopeiae. G. VAN BIESBROECK: New nebular photographs with the 82-inch McDonald reflector.

Another meeting is planned for late spring near Chicago; date and place will be announced later. I would like to take this opportunity of inviting new people who may be interested in attending meetings, or in presenting papers, to get in touch with me. With the end of the war, we hope it will be possible for more astronomers in the territory surrounding Chicago (Illinois, Indiana, Iowa, Michigan, Minnesota, and Wisconsin) to attend our meetings. There undoubtedly have been many changes of address, and of staffs; if any astronomers, or teachers of astronomy in our neighborhood would like to receive notices of future meetings, I will be delighted to have their names. The organization has a double purpose in that it provides an opportunity for discussion of new scientific work, new investigations, and also may serve to keep those now primarily interested in teaching in contact with the research activities at our group of observatories.

JESSE L. GREENSTEIN, *Secretary.*

Yerkes Observatory, Williams Bay, Wisconsin.

Summary of Sun-Spot Observations at Mount Holyoke College, 1945

Month	No. of Obs.	North of Equator No. of Groups	North of Equator Av. Lat.	South of Equator No. of Groups	South of Equator Av. Lat.	Av. No. Groups at one Obs.	New Groups
January	22	5	+23°8	3	—19°1	1.7	8
February	21	1	25.0	5	18.9	1.2	6
March	21	2	28.2	7	19.5	1.6	8
April	23	1	33.3	10	22.7	2.0	8
May	19	3	26.7	11	18.1	2.2	11
June	23	3	26.2	8	21.3	2.4	10
July	22	4	20.7	10	20.2	2.4	13
August	20	9	20.5	9	22.3	2.0	17
September	10	6	23.6	8	21.2	2.8	14
October	21	10	23.5	12	25.2	5.0	19
November	16	6	20.9	15	21.5	3.6	16
December	13	5	+20.8	3	—17.7	1.9	7
Totals	231	55		101			137

Average number of groups at one observation.....2.38
Average latitude of 50 groups north of the equator.....+23°22
Average latitude of 87 groups south of the equator.....—21°03
Number of days without spots.....16

Reviving solar activity is indicated by the increase in the number of new groups and the average number of groups at one observation. Even more strongly, the sharp decrease in the number of days without spots (from 109 in 1944 to 16 in 1945) suggests that the 1944 minimum was narrow as well as high. In previous records, the decided upturn in solar activity usually occurs when the average latitude of groups has already begun to diminish; the data for 1945 suggest more activity than usual in relatively high zones of latitude.

The year's steady increase in activity to a high in October was not thereafter maintained. Nine groups were observed on the Sun Octobr 19 and 20, only 1.6 years after sun-spot minimum; this seems to be unique in our records. During most of the year, activity has been conspicuously greater in the southern hemisphere than the northern.

ALICE H. FARNSWORTH.

John Payson Williston Observatory, South Hadley, Mass., January, 1946.

Book Reviews

Astronomy. Vol. I, The Solar System (Revised Edition), by H. N. Russell, R. S. Dugan and J. Q. Stewart. Ginn and Co., Boston.

The first edition of this excellent reference work on astronomy appeared in 1926; this is the first revision of Volume I, The Solar System. Professor Dugan has passed on, but his name is retained as an author because of his great contribution to the work. As the preface indicates, most of the work of revision has been done by Professor Russell, whose broad knowledge of the field of astronomy makes him well qualified for the task. Since the original edition is so well known and has been so widely used, the emphasis in this review will be on the changes made in it.

The number of pages in this volume is the same as in the earlier edition; in every case where new material has been added, some old has been dropped. The reader may find himself regretting that the volume was not entirely rewritten, since the original outline prejudices somewhat the choice of material. Important new developments have been crowded into fine print or omitted altogether. A considerable number of the illustrations could have been replaced by modern ones. Furthermore, changes have not always been made at every point where they are required. For example, one of the outstanding changes is in the new estimate of the mean distance, earth to sun—93,004,000 instead of 92,870,000 miles as given in the earlier edition. On page 108, the mean distance is given as 149,450,000 km. which would correspond to the older figure, and again on page 215, in the discussion of the dimensions of the earth's shadow, it is given as 92,870,000 miles. This of course means that the length given for the earth's shadow, 859,000 miles, is in error and that the size of the earth's shadow at the moon's distance as given on page 217 is wrong. On page 219 the dimensions of the moon's shadow have not been corrected to correspond to the new value of the astronomical unit.

It is pleasing to see mention made of modern navigational methods, the Schmidt camera, recent evidence concerning the age of the earth and the solar system, and a discussion of modern studies of planetary atmospheres, etc. One notices the complete omission of such important things as the photographic zenith tube, the valuable continuous time signals of the Bureau of Standards, and the Maksutov telescope. It seems unfortunate that the invention of the telescope is menioned only in a footnote referring to an out-of-print book. This emphasizes the urgent need for a good modern history of astronomy.

There are a number of places where the book is not up-to-date. For instance, on page 32 and again on page 226, it is stated that the various nautical almanacs are issued three years in advance, a statement which has not been true for a number of years. On page 70, there is a photograph of an ancient marine sextant which does not even possess a continuous tangent screw; this might well have been replaced by a photograph of a modern bubble octant. It is noted that the terms "vernal equinox" and "autumnal equinox" are used rather than the more modern terms "March equinox" and "September equinox." The definition of azimuth given on page 12 is the old-fashioned one which would measure azimuth from the south point on the horizon to the west.

One error which appeared in the first edition and which has not been cor-

rected in this, is the statement on page 228 that "the usual number of solar eclipses in a saros is about 71, varying 2 or 3 one way or the other"; the number should be 43. The fact that this erroneous statement has been copied in other books emphasizes quite well the high regard in which the volume is held by astronomers generally. Another minor change it is trusted will not be copied elsewhere, appears on page 231 where the total solar eclipse of October 2, 1959, which will be visible from southern New England, is omitted from the list of total eclipses which will be visible in the United States during the twentieth century. On the other hand, it is stated that the eclipse of March 7, 1970, will be total along the coast from Florida to North Carolina, a fact which has frequently been overlooked in other books.

One may regret the slight errors noted here but the fact remains that this book represents the best authoritative elementary reference work on the solar system available in English at the present time.

CHARLES H. SMILEY.

The Milky Way (Second Edition), by Bart J. Bok and Priscilla F. Bok. (The Blakiston Company, Philadelphia, Pa.)

The first edition of this work appeared in 1941 and was reviewed on page 566 of the volume of POPULAR ASTRONOMY for that year. In addition to the material contained in the first edition, the second edition contains a postscript in the form of Chapter 12. This chaper is designed to incorporate the advances in the study of the Milky Way since the first edition was published. Items mentioned in it are: Spectral Classes; The Nearest Stars; Cosmic Dust and the Interstellar Gas; The Structure of the Galaxy; and The Cosmic Time Scale.

As intimated in the former review, this volume may be considered as authoritative and dependable in the material with which it deals.

An Eclipse of the Moon

(December 18, 1945)

Our lovely satellite in splendor rare
Appeared low in the east one snow draped night,
When earthy shadow-fingers tried to snare
Within a web of darkness her white light.
They drew the cover slowly, skillfully;
Her glory dimmed. Man paused this scene to view,
This mass so strange, made up of shadows, wholly,
With patches here and there of lighter hue.
Then gently, as by loving hands unseen,
The veil was lifted—like a cloud rolled on.
The Moon in all her majesty, serene,
Again shone in the night sky like a sun.
In radiance new, her magic, soothing light
Poured down upon this planet, hushed and white.

LISA ODLAND.